CSIR-NET/JRF & GATE

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Assignment

Solid State Physics

(I & II)

PHYSICAL SCIENCES

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PHYSICAL SCIENCES (JRF-NET/GATE)

Assignment – I: Solid State Physics

1. The packing fraction of a simple cubic lattice is approximately:
(a) 0.74 (b) 0.68 (c) 0.52 (d) 0.34

2. Given that r is the radius of the atoms and a is the lattice constant of a solid having a cubic structure, which one of the following relations is true for a body centred cubic structure?
(a) a = 2r (b) $a = 2r\sqrt{2}$ (c) $a = 2r\sqrt{3}$ (d) $a = 4r/\sqrt{3}$

3. The crystal structure of diamond is:
(a) fcc with two atom basis of (000) and $\frac{a}{4}(\hat{i}+\hat{j}+\hat{k})$
(b) simple cubic with two atom basis of (000) and $\frac{a}{2}(\hat{i}+\hat{j}+\hat{k})$
(c) fcc with two atoms basis of (000) and $\frac{a}{2}(\hat{i}+\hat{j}+\hat{k})$
(d) bcc with one atom basis

4. The origin of van der Waals interaction of molecular crystals is:
(a) nuclear (b) magnetic (c) ionic (d) fluctuating dipolar

5. In the Meissner state the magnetic susceptibility of a super conductor in S.I. units is:
(a) $-\frac{1}{4\pi}$ (b) $\frac{1}{4\pi}$ (c) -1 (d) $-\frac{1}{\mu_o}$

6. Which of the following crystals be represented by interpenetrating lattices:
(a) Sodium (bcc structure) (b) Sodium chloride
(c) Cesium chloride (d) Diamond

7. What is the second nearest-neighbour distance in a face centred cubic lattice whose conventional unit cell parameter is a?
(a) $a/\sqrt{2}$ (b) a/2 (c) a (d) $\sqrt{2}/a$

8. Magnetic long range order is typically exhibited by:
(a) noble metals (b) alkali metals
(c) inert gas solids (d) transition metals

9. A metal with body centered cubic (bcc) structure shows the first (i.e. smallest angle) diffraction peak at Bragg angle of $\theta = 30°$. The wavelength of X-ray used is 2.1 Å. The volume of the PRIMITIVE unit cell of the metal is:
(a) 26.2 (Å)^3 (b) 13.1 (Å)^3 (c) 9.3 (Å)^3 (d) 4.6 (Å)^3.

10. The potential in a divalent solid at a particular temperature is represented by a one-dimensional periodic model. The solid should behave electrically as:
(a) semiconductor (b) a conductor
(c) an insulator (d) a superconductor

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11. In a cube system with cell edge a, two phonos with wave vectors $\vec{q}_1$ and $\vec{q}_2$ collide and produce a third phonon with a wave vector $\vec{q}_3$ such that:

$$\vec{q}_1 + \vec{q}_2 = \vec{q}_3 + \vec{R},$$

Where $\vec{R}$ is a lattice vector. Such a collision process will lead to:

(a) finite thermal resistance
(b) zero thermal resistance
(c) an infinite thermal resistance
(d) a finite thermal resistance for certain $|\vec{R}|$ only

12. For an NaCl crystal, the cell-edge a = 0.542 nm. The smallest angle at which Bragg reflection can occur corresponds to a set of planes whose indices are
(a) 100 (b) 110 (c) 111 (d) 200

13. Consider the Fermi-Dirac distribution function f(E) at room temprature (300 K) where E refers to energy. If E_F is the Fermi energy, which of the following is true?
(a) f(E) is a step function
(b) f(EF) has a value of 1/2
(c) States with $E<E_F$ are filled completely
(d) f(E) is large and tends to infinity as E decreases much below E_F

14. The effective mass of an electron in a semiconductor can be:
(a) negative near the bottom of the band
(b) a scalar quantity with a small magnitude
(c) zero at the center of the band
(d) negative near the top of the band

15. Which one of the following is TRUE for a semiconductor p–n junction with no external bias?
(a) The total charge in the junction is not conserved
(b) The p side of the junction is positively charged
(c) The p side of the junction is negatively charged
(d) No charge develops anywhere in the junction

16. Consider the energy E in the first Brillouin zone as a function of the magnitude of the wave vector k for a crystal of lattice constant a. Then
(a) the slope of E versus k is proportional to the group velocity
(b) the slope of E versus k has its maximum value at $|k| = \pi/a$
(c) the plot of E versus k will be parabolic in the interval $(-\pi/a) < k < (\pi/a)$
(d) the slope of E versus k is non-zero for all k the interval $(-\pi/a) < k (\pi/a)$

17. The specific heat of an ideal Fermi gas in 3-dimension at very low temperature (T) varies as:
(a) T (b) $T^{3/2}$ (c) T^2 (d) T^3

18. Which one of the following is the first order phase transition?
(a) Vaporization of a liquid at its boiling point
(b) Ferromagnetic to paramagnetic
(c) Normal liquid He to superfluid He } 2nd order
(d) Superconducting to normal state

19. The C/a ratio for an ideal hexagonal closed packed structure is:
(a) $\frac{2}{\sqrt{3}}$ (b) $\sqrt{8}$ (c) $\sqrt{5}$ (d) $\sqrt{\frac{8}{3}}$

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20. The effective mass of an electron in a semiconductor
(a) can never be positive (b) can never be negative
(c) can be positive or negative (d) depends on its spin

21. For a closed packed BCC structure of hard spheres, the lattice constant a is related to the sphere radius R as:
(a) $a = 4R/\sqrt{3}$ (b) $a = 4R\sqrt{3}$ (c) $a = 4R\sqrt{2}$ (d) $a = 2R\sqrt{2}$

22. An n-type semiconductor has an electron concentration of 3×10^{20} m^{-3}. If the electron drift velocity is 100 ms–1 in an electric field of 200 Vm–1, the conductivity (in $\Omega^{-1}m^{-1}$) of this material is:
(a) 24 (b) 36 (c) 48 (d) 96

23. For a conventional superconductor, which of the following statements is NOT true?
(a) Specific heat is discontinuous at transition temperature T_c
(b) The resistivity falls sharply at T_c
(c) It is diamagnetic below T_c
(d) It is paramagnetic below T_c

24. The target of an X-ray tube is subjected to an excitation voltage V. The wavelength of the emitted X-rays is proportional to:
(a) $\frac{1}{\sqrt{V}}$ (b) $\sqrt{V}$ (c) $\frac{1}{V}$ (d) V

25. Which one of the following is NOT a correct statement about semiconductors?
(a) The electrons and holes have different mobilities in a semiconductor
(b) In an n-type semiconductor, the Fermi level lies closer to the conduction band edge
(c) Silicon is a direct band gap semiconductor (it is indirect)
(d) Silicon has diamond structure

26. Which one of the following axes of rotational symmetry is NOT permissible in single crystals?
(a) two fold axis (b) three-fold axis
(d) four-fold axis (d) five-fold axis

27. Which one of the following statements about superconductors is NOT true?
(a) A type I superconductor is completely diamagnetic
(b) All type II superconductor exhibits Meissner effect upto second critical magnetic field (H_{C_2}).
(c) A type II superconductor exhibits zero reistance upto the second critical magnetic field
(d) Both type I and type II superconductors exhibit sharp fall in resistance at the superconducting transition temperature. (∵ Tc is some for both)

28. A solid superconductor is placed in an external magnetic field and then cooled below its criticalk temperature. The superconductor.
(a) retains its magnetic flux becuase the surface current supports it.
(b) expels out its magnetic flux because it behaves like a paramagnetic material.
(c) expels out its magnetic flux because it behaves like an anti-ferromagnetic material
(d) expels out its magnetic flux because the surface current induces a field in the direction opposite to the applied magnetic field.
behaves as diamagnetic

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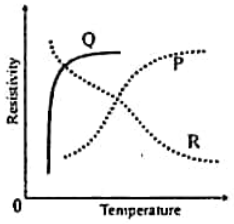
29. Consider the atomic packing factor (APF) of the following crystal structures:
P. Simple Cubic Q. Body Centred Cubic
R. Face Centred Cubic S. Diamond
T. Hexagonal Close Packed
Which two of the above structures have equal APF?
(a) P and Q (b) S and T (c) R and S (d) R and T

30. Variation of electrical resistivity ρ with temperature T of three solids is sketched (on different scales) in the figure, as curves P, Q and R.



Which of the following statements describes the variations most appropriately?
(a) P is for a superconductor and R for a semiconductor
(b) Q is for a superconductor and P for a conductor
(c) Q is for a superconductor and R for a conductor
(d) R is for a superconductor, and P for a conductor

Statement for Linked Answer Q.31 and Q.32.
The atomic density of a solid is $5.85\times10^{28}\ m^{-3}$. Its electrical resistivity is $1.6\times10^{-8}\ \Omega$ m. Assume that electrical conduction is described by the Drude model (classical theory), and that each atom contributes one conduction electron.

31. The drift mobility (in $m^2V^{-1}s^{-1}$) of the conduction electrons is:
(a) 6.67×10^{-3} (b) 6.67×10^{-6} (c) 7.63×10^{-3} (d) 7.63×10^{-6}

32. The relaxation time (mean free time), in seconds, of the conduction electrons is:
(a) 3.98×10^{-15} (b) 3.79×10^{-14} (c) 2.84×10^{-12} (d) 2.64×10^{-11}

33. Metallic monovalent sodium crystallizes in body centered cubic structure. If the length of the unit cell is 4×10^{-8} cm, the concentration of conduction electrons in metallic sodium is:
(a) $6.022\times10^{23}\ cm^{-3}$ (b) $3.125\times10^{22}\ cm^{-3}$
(c) $2.562\times10^{21}\ cm^{-3}$ (d) $1.250\times10^{20}\ cm^{-3}$

34. The primitive translation vectors of the body centered cubic lattice are $\vec{a}=\frac{a}{2}(\hat{x}+\hat{y}-\hat{z})$, $\vec{b}=\frac{a}{2}(\hat{x}+\hat{y}+\hat{z})$, and $\vec{c}=\frac{a}{2}(\hat{x}-\hat{y}+\hat{z})$. The primitive translation vectors $\vec{A},\vec{B}$ and $\vec{C}$ of the reciprocal lattice are:

(a) $\vec{A}=\frac{2\pi}{a}(\hat{x}-\hat{y});\ \vec{B}=\frac{2\pi}{a}(\hat{y}+\hat{z});\vec{C}=\frac{2\pi}{a}(\hat{x}+\hat{z})$

(b) $\vec{A}=\frac{2\pi}{a}(\hat{x}+\hat{y});\ \vec{B}=\frac{2\pi}{a}(\hat{y}-\hat{z});\vec{C}=\frac{2\pi}{a}(\hat{x}+\hat{z})$

(c) $\vec{A}=\frac{2\pi}{a}(\hat{x}+\hat{y});\ \vec{B}=\frac{2\pi}{a}(\hat{y}+\hat{z});\vec{C}=\frac{2\pi}{a}(\hat{x}-\hat{z})$

(d) $\vec{A}=\frac{2\pi}{a}(\hat{x}+\hat{y});\ \vec{B}=\frac{2\pi}{a}(\hat{y}+\hat{z});\vec{C}=\frac{2\pi}{a}(\hat{x}+\hat{z})$

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35. The structure factor of a single cell of identical atoms of form factor f is given by $Shkl = f\sum_{1}\exp\left(-i2\pi\left(x_j h + y_j k + z_j l\right)\right)$ where (x_j, y_j, z_j) is the coordinate of an atom, and hkl are the Miller indices. Which one of the following statement is correct for the diffraction peaks of body centered cubic (BCC) and face centered cubic (FCC) lattices?

(a) BCC : (200; (110); (222)
FCC : (111); (311); (400)

(b) BCC : (210); (110); (222)
FCC : (111); (311); (400)

(c) BCC : (200); (110); (222)
FCC : (111); (211); (400)

(d) BCC : (200); (210); (222)
FCC : (111); (211); (400)

36. The kinetic energy of a free electron at a corner of the first Brillouin zone of a two dimensional square lattice is larger than that of an electron at the mid-point of a side of the zone by a factor b. The value of b is:

(a) $b = \sqrt{2}$ (b) b = 2 (c) b = 4 (d) b = 8

37. Which of the following bonds has more directional:

(a) Ionic bonds (b) Covalent (c) Metalic (d) Vander Waals

38. If there are n-atoms in the primitive cell, the phonon dispersion relation had optical branches:-

(a) 3n – 3 (b) 3n – 2 (c) 3n – 1 (d) none

39. Silicon has diamond structure with unit-cell-edge a = 0.542 nm. The interatomic separation is :

(a) 0.122 nm (b) 0.234 nm (c) 0.383 nm (d) 0.542 nm.

40. A metal has free-electron density $n = 10^{29}\ m^{-3}$. Which of the following wavelengths will excite plasma oscillations?

(a) 0.033 μm (b) 0.330 μm (c) 3.300 μm (d) 33.000 μm

41. The critical magnetic field for a solid in superconducting state

(a) Does not depend upon temperature
(b) Increases if the temperature
(c) Increases if the temperature decreases
(d) Does not depend on the transition temperature.

42. Which one of the following statements is NOT TRUE?

(a) Entropy decreases markedly on cooling a superconductor below the critical temperature, T_c.
(b) The electronic contribution to the heat capacity in the superconducting state has an exponential form with an argument proportional to T^{-1}, suggestive of an energy gap
(c) A type I superconductor is a perfect diamagnet.
(d) Critical temperature of superconductors does not vary with the isotopic mass.

43. The valence electrons do not directly determine the following property of a metal.

(a) Electrical conductivity (b) Thermal conductivity
(c) Shear modulus (mechanical property) (d) metallic lustre.

44. Consider X-ray diffraction from a crystal with a face-centered-cubic (fcc) lattice. The lattice. The lattice plane for which there is NO diffraction peak is:

(a) (2, 1, 2) (b) (1, 1, 1) (c) (2, 0, 0) (d) (3, 1, 1)

45. The Hall coefficient, R_H, of sodium depends on

(a) The effective charge carrier mass and carrier density.
(b) The charge density and relaxation time.
(c) The charge carrier density only.
(d) The effective charge carrier mass.

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46. For a two-dimensional free electron gas, the electronic density n, and the Fermi energy E_F, are related by

(a) $n = \frac{(2mE_F)^{3/2}}{3\pi^2\hbar^3}$ (b) $n = \frac{mE_F}{\pi\hbar^2}$ (c) $n = \frac{mE_F}{2\pi\hbar^2}$ (d) $n = \frac{2^{3/2}(mE_F)^{1/2}}{\pi\hbar}$

47. Identify which one is a first order phase transition?
(a) A liquid to gas transition at its critical temperature.
(b) A liquid to gas transition close to its triple point.
(c) A paramagnetic to ferromagnetic transition in the absence of a magnetic field.
(d) A metal to superconductor transition in the absence of a magnetic field.

48. A superconducting ring is cooled in the presence of a magnetic field below its critical temperature (T_c). The total magnetic flux that passes through the ring is:

(a) zero (b) $n\frac{h}{2e}$ (c) $\frac{nh}{4\pi e}$ (d) $\frac{ne^2}{hc}$

49. In a cubic crystal, atoms of mass M_1 lie on one set of planes and atoms of mass M_2 lie on planes interleaved between those of the first set. If C is the force constant between nearest neighbour planes, the frequency of lattice vibrations for the optical phonon branch with wavevector k = 0 is:

(a) $\sqrt{2C\left(\frac{1}{M_1}+\frac{1}{M_2}\right)}$ (b) $\sqrt{C\left(\frac{1}{M_1}+\frac{1}{M_2}\right)}$ (c) $\sqrt{C\left(\frac{1}{M_1}+\frac{1}{2M_2}\right)}$ (d) 0

50. For a Fermi gas of N particles in three dimensions at T = 0 K, the Fermi energy, E_F

(a) $N^{2/3}$ (b) $N^{3/2}$ (c) N^3 (d) N^2

51. Compared to a p-n junction with $N_A = N_D = 10^{14}/cm^3$, which one of the following statement is TRUE for a p-n junction with $N_A = N_D = 10^{20}/cm^3$?
(a) Reverse breakdown voltage is lower and depletion capacitance is lower.
(b) Reverse breakdown voltage is higher and depletion capacitance is lower.
(c) Reverse breakdown voltage is lower and depletion capacitance is higher.
(d) Reverse breakdown voltage is higher and depletion capacitance is higher.

52. The ratio of the mobility to the diffusion coefficient in a semiconductor has the units:

(a) V^{-1} (b) $cm.V^{-1}$ (c) $V.cm^{-1}$ (d) $V.s$

53. Silicon is doped with boron to a concentration of 4×10^{17} atoms/cm^3. Assume the intrinsic carrier concentration of silicon to be 1.5×10^{10}/cm^3 and the value of kT/q to be 25 mV at 300 K. Compared to un-doped silicon, the Fermi level of doped silicon:
(a) Goes down by 0.13 eVs (b) Goes up by 0.13 eV
(c) Goes down by 0.427 eV (d) Goes up by 0.427 eV

54. The electron and hole concentrations in an intrinsic semiconductor are n_i per cm^3 at 300K. Now, if acceptor impurities are introduced with a concentration of N_A per cm^3 (where $N_A >> n_i$), the electron concentration per cm^3 at 300 K will be:

(a) n_i (b) $n_i + N_A$ (c) $N_A - n_i$ (d) $\frac{n_i^2}{N_A}$

55. In a p^+ n junction diode under reverse bias, the magnitude of electric field is maximum at:
(a) The edge of the depletion region on the p-side (b) The edge of the depletion region on the n-side
(c) The p^+ n junction (d) The centre of the depletion region on the n-side.

56. A P^+–N junction has a built-in potential of 0.8 V. The depletion layer width at a reverse bias of 1.2 V is 2 μm. For a reverse bias of 7.2 V, the depletion layer width will be:

(a) 4 μm (b) 4.9 μm (c) 8 μm (d) 12 μm

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57. The majority carriers in n-type semiconductor have an average drift velocity V in a direction perpendicular to a uniform magnetic field B. The electric field E induced due to Hall effects acts in the direction:
(a) V×B (b) B×V (c) along V (d) opposite to V

58. The bandgap of silicon at room temperature is:
(a) 1.3 eV (b) 0.7 eV (c) 1.1 eV (d) 1.4 eV

59. A silicon PN junction diode under reverse bias has depletion region of width 10 μm. The relative permitivity of Silicon, $\varepsilon_r = 11.7$ and the permitivity of free space $\varepsilon_o = 8.85 \times 10^{-12}\ F/m$. The depletion capacitance of the diode per square metter is:
(a) 100 μF (b) 10 μF (c) 1 μF (d) 20 μF

60. In an abrupt p-n junction, the doping concentrations on the p-side and n-side are $N_A = 9\times10^{16}/cm^3$ and $N_D = 1\times10^{16}/cm^3$ respectively. The p-n junction is reverse biased and the total depletion width is 3 μm. The depletion width on the p-side is:
(a) 2.7 μm (b) 0.3 μm (c) 2.25 μm (d) 0.75 μm

61. The longest wavelength that can be absorbed by silicon, which has the band-gap of 1.12 eV, is 1.1μm. If the longest wavelength that can be absorbed by another material is 0.87 μm, then the bandgap of this material is:
(a) 1.416 eV (b) 0.886 eV (c) 0.854 eV (d) 0.706 eV

62. N-type silicon bar 0.1 cm long and 100 μm^2 in cross-sectional area has a majority carrier concentration of $5\times10^{20}/cm^3$ and the carrier mobility is 0.13 m^2/V-s at 300 K. If the charge of an electron is 1.6×10^{-19} coulomb, then the resistance of the bar is:
(a) 10^6 ohm (b) 10^4 ohm (c) 10^{-1} ohm (d) 10^{-4} ohm

63. A particular green LED emits light of wavelength 5490Å. The energy bandgap of the semiconductor material used there is (Planck's constant = 6.626×10^{-34} J-s):
(a) 2.26 eV (b) 1.98 eV (c) 1.17 eV (d) 0.74 eV

64. A long specimen of p-type semiconductor material:
(a) Is positively charged (b) Is electrically neutral
(c) Has an electric field directed along its length (d) Acts as a dipole

65. The probability that an electron in a metal occupies the Fermi-level at any temperature (> 0 K):
(a) 0 (b) 1 (c) 0.5 (d) 1.0

66. In a P-type silicon sample, the hole concentration is $2.25\times10^{15}/cm^3$. If the intrinsic carrier concentration is $1.5\times10^{10}/cm^3$, the electron concentartion is:
(a) Zero (b) $10^{10}/cm^3$ (c) $10^5/cm^3$ (d) $1.5\times10^{25}/cm^3$

67. An infra-red LED is usually fabricated from:
(a) Ge (b) Si (c) Ga As (d) Ga As P

68. Which of the following statements is/are true for a good conductor of electricity?
1. Its conductivity decreases with increasing temperature.
2. Number of free electrons is around $10^{28} m^{-3}$.
3. Its conductivity decreases with addition of impurities.
4. It is a good conductor of heat also.
(a) 1, 2, 3 and 4 (b) 1 only (c) 2 and 3 only (d) 3 and 4 only

69. Consider the following statements:
The conductivity of a metal has negative temperature coefficient since:
1. The electron concentration increases with temperature. (Remain constant)
2. The electron mobility decreases with temperature. $\longrightarrow \mu \propto T \propto T^{-1}$
3. The electron-lattice scattering rate increases with temperature.

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Which of the above statements is/are correct?
(a) 1 only (b) 1 and 2 (c) 2 and 3 (d) 3 only

70. Which one of the following is a trivalent material?
(a) Antimony (b) Phosphorus (c) Arsenic (d) Boron

71. Consider the following:
1. Si 2. Ge 3. GaAs 4. In P
Which of the above semiconductors should be used for making highly efficient photodiodes?
(a) 1 and 4 only (b) 3 and 4 only (c) 1, 3 and 4 (d) 2, 3 and 4.

72. The materials not having negative temperature coefficient of resistivity are
(a) Metals (b) Semiconductors (c) Insulators (d) None of the above.

73. In a materials, the Fermi level is located between the centre of the forbidden band and the conduction band. Then what is that material?
(a) A p-type semiconductor (b) An n-type semiconductor
(c) An intrinsic semicondutor (d) An insulator.

74. An intrinsic semiconductor with energy gap 1 eV has a carrier cocentration N at temperature 200 K. Another intrinsic semiconductor has the same value of carrier concentration N at temperature 600K. What is the energy gap value for the second semiconductor?
(a) (1/3) eV (b) (3/2) eV (c) 3 eV (d) 9 eV

75. Consider the following statements:
n-type of silicon can be
1. Formed by adding impurity of phosphorus
2. Formed by adding impurity of arsenic
3. Formed by adding impurity of boron.
4. Formed by adding impurity of aluminium.
Which of the statements given above are correct?
(a) 1 and 3 only (b) 3 and 4 only (c) 1 and 2 only (d) 1, 2, 3 and 4.

76. Consider the following statements for a photo conducting material:
1. Its dark conductivity is small.
2. With the absorption of radiation, equal numbers of electrons and of holes are produced.
Which of the statements given above is/are correct?
(a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2.

77. In a step-graded p-n junction diode, what is the ratio of depletion-region penetration depths into p and n regions (if the ratio of acceptor to donor impurity atoms densities is 1:2)?
(a) 2:1 (b) 4:1 (c) 1:2 (d) 1:4

78. Match **List-I** with **List-II** and select the corret answer using the code given below the lists:

List-I (Item)	**List-II (Position)**
A. Donor energy band	1. At the middle of the forbidden energy gap.
B. Fermi level of p-type semiconductor at room temperature	2. Close to the conduction band.
C. Acceptor energy band	3. Very close to the valance band.
D. Fermi level in intrinsic semiconductor	4. Close to the valence band.

Code:

	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

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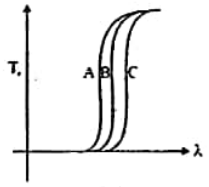
79. The depletion layer in a p-n junction is made of which of the following?
(a) Ionized donors in p-side and ionized acceptors in n-side.
(b) Ionized acceptors in p-side and ionized donors in n-side.
(c) Accumulated holes in p-side and accumulated electrons in n-side.
(d) Accumulated electrons in p-side and accumulated holes in n-side.

80. Photovoltaic devices may be made from various semiconductors as optical materials for which the transmission coefficient (T_i) is shown in the figure given below as a function of photon wavelength.



Which one of the following is the correct sequence of A, B and C pertaining to Ge, Ga, As and Si, respectively?
(a) A–B–C (b) B–A–C (c) C–A–B (d) C–B–A

81. Match the **List-I**(Current) with **List-II** (Variation) and select the correct answer using the code given below the lists:

List-I (Current)	**List-II (Variation)**
A. Hole deffusion current	1. n.E
B. Electron drift current	2. p.E
C. Hole drift current	3. –dp/dx
D. Electron diffusion current	4. dn/dx

(a) A-2, B-1, C-3, D-4 (b) A-3, B-4, C-2, D-1
(c) A-2, B-4, C-3, D-1 (d) A-3, B-1, C-2, D-4

82. Photons of energy 1.53×10^{-19} Joule are incident on a photodiode which has a responsivity of 0.65 A/W. If the optical power level is 10 μW . What is the photo current generated?
(a) 64 nA (b) 1.5 μA (c) 2.1 μA (d) 6.5 μA

83. A thin resistive film having length (l), width (w) and thickness (t) is used as a resistor (R_1) for conducting current in the direction of l. If the film is connected to serve as a resistor (R_2) for conducting current in the direction of w, then what is the value of R_1/R_2.
(a) l/w (b) w/l (c) l^2/w^2 (d) w^2/l^2.

84. **Match List-I (Type of Material)** with **List-II (Type of Bonding)** and the select the correct answer using the codes given below the lists:

List-I (Typed of Material)	**List-II (Type of Bonding)**
A. Elemental semiconductor	1. Ionic
B. Hydrogen molecule	2. Covalent
C. Copper	3. Van der Waals'
D. AgI	4. Metallic.

Codes:

(a)	A-3	B-2	C-1	D-4	(b)	A-2	B-3	C-1	D-4
(c)	A-2	B-3	C-4	D-1	(d)	A-3	B-4	C-2	D-1

85. An LED made usig GaAs emits radiation in:
(a) Visile region (b) Ultraviolet region
(c) Infra red region (d) Microwave frequency region.

86. The light emitting diode (LED) emits light of a particular colour because
(a) It is fabricated from a fluorescent material.
(b) Transition between energy levels of the carriers takes place while crossing the p-n junction.
(c) Heat generated in the diode is converted into light.
(d) The band gap of the semi-conductor material used in fabrication of the diode is equal to the energy h_v of the light photon.

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87. Depletion capacitance in a diode depends on:
1. Applied junction voltage. 2. Junction built-in potential
3. Current through junction 4. Doping profile across the junction
Select the correct answer using the codes given below:
(a) 1 and 2 (b) 1 and 3 (c) 1, 2 and 4 (d) 2, 3 and 4

88. The depletion layer across a p^+-n junction lies
(a) mostly in the p region (b) mostly in the n region
(c) equally in both p^+ and n regions (d) Entirely in the p^+ region.

89. The Ohm's law for conduction in metals is:
(a) $J = \sigma E$ (b) $J \propto \sigma E$ (c) $J = E/\sigma$ (d) $J \propto E/\sigma$

90. Match **List-I (Crystal type)** with **List-II (Name of the solid)** and select the correct answer using the codes given below the Lists:

List-I	**List-II**
A. Ionic	1. Solid argon
B. Covalent	2. Copper
C. Metallic	3. Silicon
D. Van der Waal's	4. Sodium chloride

Codes:
(a) A-3 B-4 C-2 D-1 (b) A-4 B-3 C-1 D-2
(c) A-3 B-4 C-1 D-2 (d) A-4 B-3 C-2 D-1

91. The carrier mobility in a semiconductor is 0.4 m^2/Vs. Its diffusion constant at 300 K will be (in m^2/s)
(a) 0.43 (b) 0.16 (c) 0.04 (d) 0.01

92. GaAs has an energy gap 1.43 eV. The optical cut-off wavelength of GaAs would lie in the
(a) Visible region of the spectrum (b) Infrared region of the spectrum
(c) Ultraviolet region of the spectrum (d) Far ultraviolet region of the spectrum

93. At very high temperatures, the extrinsic semiconductors become intrinsic because
(a) Of drive-in diffusion of dopants and carries
(b) Band to band transition dominates over impurity ionization.
(c) Impurity ionization dominates over band to band transition.
(d) Band to band transition is balanced by impurity ionization

94. Given that the band gap of cadmium sulphide is 2.5 eV, the maximum photon wavelength, for electron-hole pair generation will be
(a) 5400 μm (b) 540 μm (c) 5400Å (d) 540 Å

95. The increasing temperature, the electrical conductivity would:
(a) Increase in metals as well as in intrinsic semiconductor
(b) Increase in metals but decrease in intrinsic semiconductor
(c) Decrease in metals but increase in intrinsic semiconductor
(d) Decrease in metals as well as in intrinsic semiconductors.

96. Which one of the following statements with reference to effective mass is incorrect?
(a) It is a function of wave vector K
(b) It can be positive or negative
(c) It is different from free mass because of lattice interaction
(d) Its concept is applicable only to electrons and not to holes.

97. Hall effect is observed in a specimen when it (metal or a semiconductor) is carrying current and is placed in a magnetic field. The resultant electric field inside the specimen will be in
(a) A direction normal to both current and magnetic field.
(b) The direction of current
(c) A direction antiparallel to magnetic field
(d) An arbitrary direction depending upon the conductivity of the specimen.

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98. The minority carrier life-time and diffusion constant in a semiconducting material are respectively 100 microsecond and 100 cm^2/s. The diffusion length of the carriers is:
(a) 0.1 cm (b) 0.01 cm (c) 0.0141 cm (d) 1 cm

99. The wavelength of light emitted by a GaAs laser s 8670×10^{-10} m. Given Planck's constant = 6.626×10^{-34} Js, velocity of light = 2.998×10^8 m/s and 1 eV = 1.602×10^{-19} J, the energy gap in GaAs is
(a) 0.18 eV (b) 0.7 eV (c) 1.43 eV (d) 2.39 eV

100. The difference between the electron and hole of a semiconductor laser is 1.5 eV and the band gap of the semiconductor is 1.43 eV. The upper and lower frequency limits of the laser will be respectively
(a) 3.3×10^{14} and 9.9×10^{13} Hz (b) 3.7×10^{14} and 3.5×10^{14} Hz
(c) 6.28×10^{14} and 3.1×10^{14} Hz (d) 1.16×10^{15} and 8.97×10^{14} Hz

101. The order of magnitude of the energy gap of a typical superconductor is:
(a) 1 MeV (b) 1 KeV (c) 1 eV (d) 1 meV

102. For a three-dimensional crystal having N primitive unit cells with a basis of p atoms, the number optical branches is:
(a) 3 (b) 3p (c) 3p–3 (d) 3N–3p

103. For a intrinsic semiconductor, m_e^* and m_h^* are respectively the effective masses of electrons and holes near the corresponding band edges. At a finite temperature, the position of hte Fermi level
(a) Depends on m_e^* but not on m_h^* (b) Depends on m_h^* but not on m_e^*
(c) Depends on m_e^* and m_h^* (d) depends neither on m_e^* nor on m_h^*

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Assignment-II: Solid State Physics

1. Ionic crystals are very good insulators at room temperature conducting at higher temperatures. This is due to:
   (a) Thermal expansion of the ionic solid
   (b) Generation of more free electrons
   (c) Transition of large number of electrons from valence band
   (d) Movement of larger number of ions in vacancies

2. At low temperature the specific heat of insulating crystals varies as:
   (a) AT^3 (b) $BT + CT^3$
   (c) D exp (E/T) (d) will not change with temperature

3. The band gap at 300°K of diamond cubic crystals of C, Si, Ge and Sn is 5.5, 1.2, 0.67 and 0.1 eV respectively. Identify the crystal which will have the highest electrical condictivity at 300 K
   (a) Ge (b) Sn (c) C (d) Si

4. The $\theta - 2\theta$ X-ray powder diffraction pattern of ionic crystals KCl and KBr both of which form fcc structure will have:
   (a) same number of diffraction lines with equal intensities
   (b) pattern of KBr will have more lines
   (c) Pattern of KCl will have more lines
   (d) number of lines will be same but their intensities will be different

5. A lattice is characterized by the following primitive vectors (in angstroms) :
   $\vec{a} = 2(\hat{i} + \hat{j}), \vec{b} = 2(\hat{j} + \hat{k}), \vec{c} = 2(\hat{k} + \hat{i})$. The reciprocal lattice corresponding to the above is:
   (a) body centered cubic lattice with cube edge π Å^{-1}
   (b) body centered cubic lattice with cube edge 2π Å^{-1}
   (c) face centered cubic lattice with cube edge π Å^{-1}
   (d) face centered cubic lattice with cube edge 2π Å^{-1}

6. Experimental study shows that there exists an energy gap in a superconductor. Which one of the following statements is incorrect?
   (a) The gap separates the lowest excited state in a superconductor from the ground state.
   (b) The temperature dependence of electronic specific heat indicates the existence of an energy gap.
   (c) The existence of an energy gap is accounted for in the BCS theory.
   (d) The energy gap in supercondocturs is similar to the energy gap which occurs in insulators.

7. The resistivity of metals: (below debey Temp) ($\theta < \theta_D$)
   (a) Always varies as T^5
   (b) is independent of temperature
   (c) increases liniearly with temperature at room temperature and above
   (d) attains a constant value as temperature tends to absolute zero

8. Magnons in ferromagnets: (To decrease the free energy (To stabalize))
   (a) decrease the magnetization
   (b) increase the magnetization
   (c) stabilize the magnetization
   (d) cause critical magnetic fluctuations

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9. X-rays with a wave vector $\vec{K}$ are scattered from a simple cubic lattice with lattice spacing a = 2π. The scattered X-rays have wave vector $\vec{K}$. The possible values of $\Delta K_1 = K_x - K'_x$ for which there are peaks in the scattered intensity are:
(a) $0 \leq \Delta K_1 \leq p/4$ (b) ΔK_x = integer
(c) ΔK_x = integer multiple of 2π (d) ΔK_x = integer/2π

10. For an energy state E of a photon gas, the density of states is proportional to:
(a) $\sqrt{E}$ (b) E (c) $E^{3/2}$ (d) E^2

11. In a one-dimensional Kroning Penny model, the total number of possible wave functions is equal to:
(a) twice the number of unit cells
(b) number of unit cells
(c) half the number of unit cells
(d) independent of the number of unit cells

12. For a perfect free-electron gas in a metal, the magnitudes of phase velocity (v_p) and group velocity (v_g) are such that:
(a) $v_p = v_g$ (b) $v_p = \frac{1}{2} v_g$ (c) $v_p = \sqrt{2} v_g$ (d) $v_p = 2 v_g$

13. A second order phase transition is one in which:
(a) the plot of entropy as a function of temeprature shows a discontinuity
(b) the plot of specific heat as a function of temperature shows a discontinuity
(c) the plot of volume as a function of pressure shows a discontinuity
(d) the plot of comprehensibility as a function of temperature is continuous

14. A cubic cell consists of two atoms of masses m_1 and m_2 ($m_1 > m_2$) with m_1 and m_2 atoms situated on alternate planes. Assuming only nearest neighbour interactions, the center of mass of the two atoms:
(a) moves with the atoms in the optical mode and remains fixed in the acoustic mode
(b) remains fixed in the optical mode and moves with the atoms in the acoustic mode
(c) remains fixed in both optical and acoustic modes
(d) moves with the atoms in both optical and acoustic modes

15. In simple metals the phonon contribution to the electrical resistivity at temperature T is:
(a) directly proportional to T above Debye temperature and to T^3 below it.
(b) inversely proportional to T for all temperatures
(c) independent of T for all temperatures
(d) directly proportional to T above Debye temperature and to T^5 below it

16. An external magnetic field of magnitude H is applied to a Type-I superconductor at a temperature below the transition ponit. Then which one of the following statements is NOT true for H less than the ciritical field H_c?
(a) the sample is diamagnetic
(b) it magnetization varies linearly with H
(c) the lines of magnetic induction are pushed out from the sample
(d) the sample exhibits mixed states of magnetization near H_c (TYPE II)

17. A ferromagnetic material has a Curie temperature 100 K. Then:
(a) its succeptibility is double when it is cooled from 300 K to 200 K
(b) all the atomic magnets in it get oriented in the same direction above 100 K
(c) the plot of inverse susceptibility versus temperature is linear with a slope T_c (Wrong)
(d) the plot if its succeptibility versus temperature is linear with an intercept T_c (Wrong)

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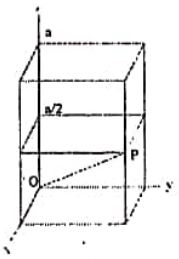
Common Data for Q. 18 and Q. 19.
Acrystal belongs to a face centered cubic lattice with four atoms in the unit cell. The size of the crystal is 1 cm and its unit cell dimension is 1 nm. f is the scattering factor of the atom.

18. The number of atoms in the crystal is:
(a) 2×10^{21} (b) 4×10^{21} (c) 2×10^{23} (d) 4×10^{24}

19. The structure factors for (0 1 0) and (2 0 0) reflections respectively are:
(a) 2 f and zero (b) zero and 4 f (c) 2 f and 2 f (d) zero and zero

20. In crystallographic notation the vector $\overline{OP}$ in the cubic cell shown in the figure is:



(a) [2 2 1] (b) [1 2 2] (c) [1 2 1] (d) [1 1 2]

21. The de Broglie wavelength λ for an electron of energy 150 eV is:
(a) 10^{-8} m (b) 10^{-10} m (c) 10^{-12} m (d) 10^{-14} m

22. The energy of a ferromagnet as a function of magnetization M is given by:
$$F(M) = F_0 + 2(T - T_C) M_2 + M_4, F_0 > 0$$
The number of minima in the function F(M) for $T > T_C$ is:
(a) 0 (b) 1 (c) 3 (d) 4

23. Density of states of free electrons in a solid moving with an energy 0.1 eV is given by 2.15×10^{21} eV^{-1} cm^{-3}. The density of states in eV^{-1} cm^{-3}) for electrons moving with an energy of 0.4 eV will be:
(a) 1.07×10^{21} (b) 1.52×10^{21} (c) 3.04×10^{21} (d) 4.30×10^{21}

24. The effective density of states at the conduction band edge of Ge is 1.04×10^{19} cm^{-3} at room temeprature 300 K). Ge has an optical bandgap of 0.66 eV. The intrinsic carrier concentration (in cm^{-3}) in Ge at room temperature (300 K) is approximately:
(a) 3×10^{10} (b) 3×10^{13} (c) 3×10^{16} (d) 6×10^{16}

Statement for Linked Answer Q. 25 and Q. 26.
Lead has atomic weight of 207.2 amu and density of 11.35 gm cm^{-3}.

25. Number of atoms per cm^3 for lead is:
(a) 1.1×10^{25} (b) 3.3×10^{22} (c) 1.1×10^{22} (d) 3.3×10^{25}

26. If the energy of vacancy formation in lead is 0.55 eV/atom, the number of vacancies cm^3 at 500K is:
(a) 3.2×10^{16} (b) 3.2×10^{19} (c) 9.5×10^{19} (d) 9.5×10^{16}

27. Which one of the following statements is NOT correct about the Brillouin zones (BZ) of a square lattices with constant a?
(a) The first BZ is a square of size $2\pi/a$ in k_x–k_y plane
(b) The areas of the first BZ and third BZ are the same
(c) The k-points are equidistant in k_x as well as in k_y directions
(d) The area of the second BZ is twice that of the first BZ

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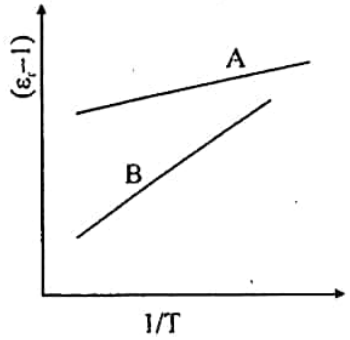
28. In a crystal of N primitive cells, each cell contains two monovalent atoms. The highest occupied energy band of the crystal is:
(a) one-fourth filled (b) one-third filled
(c) half filled (d) completely filled

29. Two dielectric materials A and B exhibit both ionic and orientational polarizabilities. The variation of the susceptibilities $c(=\varepsilon_r-1)$ with temperature T is shown in the figure, where ε, is the relative dielectric constant. It can be inferred from the figure that:



(a) A is more polar and it has a smaller value of ionic polarizability than that of B
(b) A is more polar and it has a higher value of ionic polarizability than that of B
(c) B is more polar and it has a higher value of ionic polarizability than that of A
(d) B is more polar and it has a smaller value of ionic polarizability than that of A

Statement for Linked Answer Q.30 and Q.31.

The powder diffraction pattern of a body centred cubic crystal is recorded by using Cuk_α X-rays of wavelength 1.54Å.

30. If the (002) planes diffract at 60°, then lattice parameter is:
(a) 2.67 Å (b) 3.08 Å (c) 3.56 Å (d) 5.34 Å

31. Assuming the atomic mass of the constituent atoms to be 50.94 amu, then density of the crystal in units of kg m^{-3} is:
(a) 3.75×10^3 (b) 4.45×10^3 (c) 5.79×10^3 (d) 8.89×10^3

32. When liquid oxygen is poured down close to a strong bar magnet, the oxygen stream is:
(a) repliecd towards the lower field because it is diamagnetic
(b) attracted towards the higher field because it is diamagnetic
(c) repelled towards the lower field becaue it is paramagnetic
(d) attracted towards the higher field because it is paramagnetic

33. In a powder differaction pattern recorded from a face-centred cubic sample using x-rays, the first peak appears at 30°. The second peak will appear at:
(a) 32.8° (b) 33.7° (c) 34.8° (d) 35.3°

34. An extrinsic semiconductor sample of cross-section A and length L is doped in such a way that the doping concentration varies as $N_D(x) = N_0 \exp\left(-\frac{x}{L}\right)$, where N_0 is a constant. Assume that the mobility μ of the majority carriers remains constant. The resistance R of the sample is given by:

(a) $R = \frac{L}{A\mu eN_0}\left[\exp(1.0)-1\right]$ (b) $R = \frac{L}{\mu eN_0}\left[\exp(1.0)-1\right]$

(c) $R = \frac{L}{A\mu eN_0}\left[\exp(-1.0)-1\right]$ (d) $R = \frac{L}{A\mu eN_0}$

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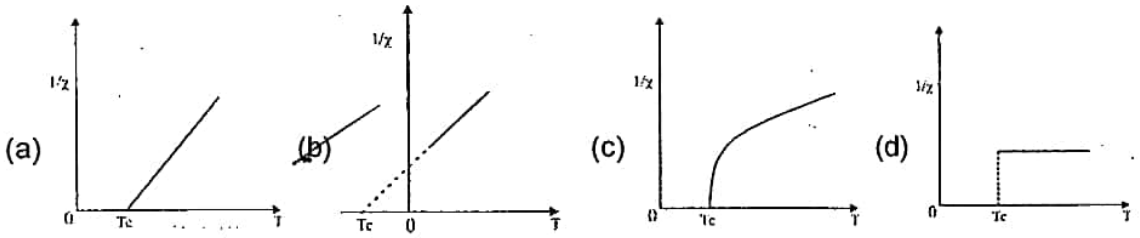
35. A ferromagnetic mixture of iron and copper having 75% atoms of Fe exhibits a saturation magnetization of 1.3×10^6 A m^{-1}. Assume that the total number of atoms per unit volume is 8×10^{28} m^{-3}. The magnetic moment of an iron atom, in terms of the Bohr Magneton, is:
(a) 1.7 (b) 2.3 (c) 2.9 (d) 3.8

36. The plot of inverse magnetic susceptibility $\frac{1}{\chi}$ versus temperature T of an antiferromagnetic sample corresponds to:



37. The lattice specific heat C of a crystalline solid can be obtained using the Dulong Petit model. Einstein modle and Debye model. At low tesmperature $h\omega >> k_B T$, which one of the following statements is true (a and A are constants)

(a) Dulong Petit : $C \propto \exp\left(\frac{-a}{T}\right)$; Einstein: C = constant; Debye : $C \propto \left(\frac{T}{A}\right)^3$

(b) Dulong Petit : C = constant; Einstein: $C \propto \left(\frac{T}{A}\right)^3$ Debye : $C \propto \left(\frac{-a}{T}\right)$

(c) Dulong Petit : C = constant; Einstein: $C \propto \frac{e^{-a/T}}{T^2}$ Debye : $C \propto \left(\frac{T}{A}\right)^3$

(d) Dulong Petit : $C \propto \left(\frac{T}{A}\right)^3$; Einstein: $C \propto \frac{e^{-a/T}}{T^2}$ Debye : C = constant

38. A linear diatomic lattice of lattice constant a with masses M and m (M > m) are coupled by a force constant C. The dispersion relation is given by:

$$\omega_{\pm}^2 = C\left(\frac{M+m}{Mm}\right) \pm \left[C^2\left(\frac{M+m}{M}\right)^2 - \frac{4C^2}{Mm}\sin^2\frac{ka}{2}\right]^{1/2}$$

Which one of the following statements is incorrect?
(a) The atoms vibrating in transverse modecorrespond to the optical branch
(b) The maximum frequency of the acoustic branch depends on the mass of the lighter atom m.
(c) The dispersion of frequency in the optical branch is smaller than that in the acoustic branch.
(d) No normal modes exist in the acoustic branch for any frequency greater than the maximum frequency at $k = \frac{\pi}{a}$.

39. Which is loose packed structure?
(a) Body centred cubic structure (b) Hexagonal close-packed structure
(c) Face-centred cubic structure (d) None of these

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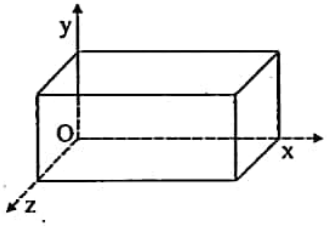
40. A doped Germanium crystal of length 2 cm, breadth 1 cm and width 1 cm, carries a current of 1 mA along its length parallel to +x axis. A magnetic field of 0.5 T is applied along +z axis. Hall voltage of 6 mV is measured with negative polarity at y = 0 plane. The sign and concentration of the majority charge carrier are, respectively [Given : $e = 1.6\times10^{-19}C$]

(a) Positive and $5.2\times10^{19}\ m^{-3}$

(b) Negative and $5.2\times10^{19}\ m^{-3}$

(c) Positive and $10.4\times10^{19} m^{-3}$

(d) Negative and $10.4\times10^{19} m^{-3}$



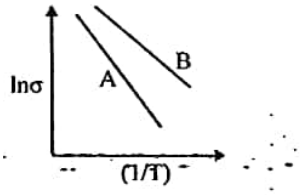
41. The temperature dependence of the electrical conductivity σ of two intrinsic semi-conductors A and B is shown in the figure. If E_A and E_B are the band gaps of A and B respectively, which one of the following is TRUE?

(a) $E_A > E_B$

(b) $E_A < E_B$

(c) $E_A = E_B$

(d) E_A and E_B both depend on temperature.



42. If the static dielectric constant of NaCl crystal is 5.6 and its optical refractive index is 1.5, the ratio of its electric polarizability to its total polarizability is:

(a) 0.5 (b) 0.7 (c) 0.8 (d) 0.9

43. Which one of the following statements is TRUE?

(a) Magnetic tapes are made of Iron.

(b) Permanent magnets are made from ferrites.

(c) Ultrasonic transducers are made from quartz crystals.

(d) Optoelectronic devices are made from soft ferrites

44. The Bloch theore states that within a crystal, the wavefunction, $\psi(\vec{r})$, of an electron has the form

(a) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{k}.\vec{r}}$ where $u(\vec{r})$ is an arbitrary function and $\vec{k}$ is an arbitrary vector.

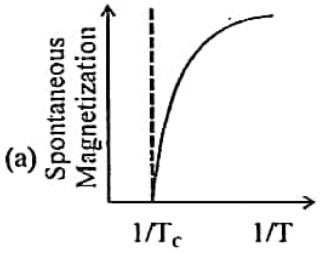
(b) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{G}.\vec{r}}$ where $u(\vec{r})$ is an arbitrary function and $\vec{G}$ is a reciprocal lattice vector.

(c) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{G}.\vec{r}}$ where $u(\vec{r}) = u(\vec{r}+\vec{\Lambda})$, $\vec{\Lambda}$ is a lattice vector and $\vec{G}$ is a reciprocal lattice vector.

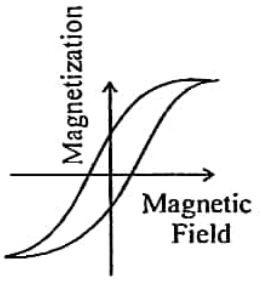
(d) $\psi(\vec{r}) = u(\vec{r})e^{i\vec{k}.\vec{r}}$ where $u(\vec{r}) = u(\vec{r}+\vec{\Lambda})$, $\vec{\Lambda}$ is a lattice vector and $\vec{k}$ is an arbitrary vector.

45. In an experiment involving a ferromagnetic medium, the following observations were made. Which one of the plots does NOT correctly represented the property of the medium? (T_C is the Curie temperature)

(a)



(b)



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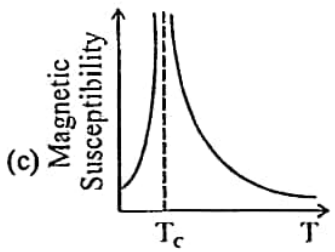
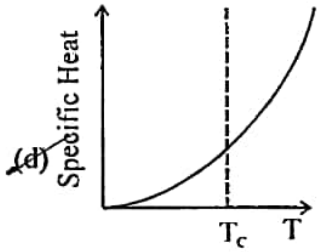
(c)


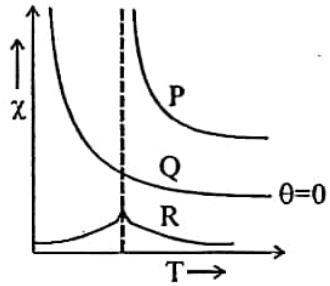
(d)


46. The thermal conductivity of a given material reduces when it undergoes a transition from its normal state to the superconducting state. The reason is:
(a) The cooper pairs cannot transfer energy to the lattice.
(b) Upon the formation of cooper pairs, the lattice becomes less efficient in heat transfer.
(c) The electrons in the normal state lose their ability to transfer heat because of their coupling to the cooper pairs.
(d) The heat capacity increases on transition to the superconducting state leading to a reduction in thermal conductivity.

47. Far away from any of the resonance frequencies of a medium, the real part of the dielectric permitivity is:
(a) Always independent of the frequency (b) Monotonically decreasing with frequency
(c) Monotonically increasing with frequency (d) A non-monotonic function of frequency.

48. In an insulating solid which one of the following physical phenomena is a coonsequence of Pauli's exclusion principle?
(a) Ionic conductivity (b) Ferromagnetism (c) Paramagnetism (d) Ferroelectricity.

49. The dependence of the magnetic susceptibility (χ) of a material with temperature (T) can be represented by $\chi \propto \frac{1}{T-\theta}$, where θ is the Curie-Weiss temperature. The plot of magnetic susceptibility versus temperature is sketched in the figure, as curves P, Q and R with curve Q having $\theta = 0$. Which one of the following statements is correct?



(a) Curve R represents a paramagnet and Q a ferromagnet.
(b) Curve Q represents a ferromagnet and P an anterromagnet.
(c) Curve R represents an antiferromagnet and Q a paramagnet.
(d) Curve R represents an antiferromagnet and Q a ferromanget.

50. The dielectric constant of a material at optical frequencies is mainly due to
(a) Ionic polarizability. (b) Electronic polarizability
(c) Dipolar polarizability (d) Ionic and dipolar polarizability.

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51. An electron of wavevector $\vec{k}_e$, velocity $\vec{\upsilon}_e$ and effective mass m_e is removed from a filled energy band. The resulting hole has wavevevtor $\vec{k}_h$, velocity $\vec{\upsilon}_h$, and effective mass m_h. Which one of the following statements is correct?

(a) $\vec{k}_h = -\vec{k}_e; \vec{\upsilon}_h = \vec{\upsilon}_e; m_h = -m_e$ (b) $\vec{k}_h = \vec{k}_e; \vec{\upsilon}_h = \vec{\upsilon}_e; m_h = m_e$

(c) $\vec{k}_h = \vec{k}_e; \vec{\upsilon}_h = -\vec{\upsilon}_e; m_h = -m_e$ (d) $\vec{k}_h = -\vec{k}_e; \vec{\upsilon}_h = \vec{\upsilon}_e; m_h = -m_e$

Linked Answer Questions:

Statement for Linked Answer Q.52 and Q. 53:

The primitive translatin vectors of the face centered cubic (fcc) lattice are

$$\hat{a}_1 = \frac{a}{2}\left(\hat{j}+\hat{k}\right);\ \hat{a}_2 = \frac{a}{2}\left(\hat{i}+\hat{k}\right); a_3 = \frac{a}{2}\left(\hat{i}+\hat{j}\right)$$

52. The primitive translation vectos of the fcc reciprocal lattice are

(a) $\hat{b}_1 = \left(\frac{2\pi}{a}\right)\left(-\hat{i}+\hat{j}+\hat{k}\right); \hat{b}_2 = \left(\frac{2\pi}{a}\right)\left(\hat{i}-\hat{j}+\hat{k}\right); \hat{b}_3 = \left(\frac{2\pi}{a}\right)\left(\hat{i}+\hat{j}-\hat{k}\right)$

(b) $\hat{b}_1 = \left(\frac{\pi}{a}\right)\left(-\hat{i}+\hat{j}+\hat{k}\right); \hat{b}_2 = \left(\frac{\pi}{a}\right)\left(\hat{i}-\hat{j}+\hat{k}\right); \hat{b}_3 = \left(\frac{\pi}{a}\right)\left(\hat{i}+\hat{j}-\hat{k}\right)$

(c) $\hat{b}_1 = \left(\frac{\pi}{2a}\right)\left(-\hat{i}+\hat{j}+\hat{k}\right); \hat{b}_2 = \left(\frac{\pi}{2a}\right)\left(\hat{i}-\hat{j}+\hat{k}\right); \hat{b}_3 = \left(\frac{\pi}{2a}\right)\left(\hat{i}+\hat{j}-\hat{k}\right)$

(d) $\hat{b}_1 = \left(\frac{3\pi}{a}\right)\left(-\hat{i}+\hat{j}+\hat{k}\right); \hat{b}_2 = \left(\frac{3\pi}{a}\right)\left(\hat{i}-\hat{j}+\hat{k}\right); \hat{b}_3 = \left(\frac{3\pi}{a}\right)\left(\hat{i}+\hat{j}-\hat{k}\right)$

53. The volume of the primitive cell of the fcc reciprocal lattice is:

(a) $4\left(\frac{2\pi}{a}\right)^3$ (b) $4\left(\frac{\pi}{a}\right)^3$ (c) $4\left(\frac{\pi}{2a}\right)^3$ (d) $4\left(\frac{3\pi}{a}\right)^3$

54. An intrinsic semiconductor with mass of a hole m_h and mass of an electron m_C is at a finite temperature T. If the top of the valence band enegy is E_V and the bottom of the conduction band energy is E_C, the Fermi energy of the semiconductor is:

(a) $E_F = \left(\frac{E_V + E_C}{2}\right) - \frac{3}{4}k_B T \ln\left(\frac{m_h}{m_e}\right)$ (b) $E_F = \left(\frac{k_B T}{2}\right) + \frac{3}{4}(E_V + E_C)\ln\left(\frac{m_h}{m_e}\right)$

(c) $E_F = \left(\frac{E_V + E_C}{2}\right) + \frac{3}{4}k_B T \ln\left(\frac{m_h}{m_e}\right)$ (d) $E_F = \left(\frac{k_B T}{2}\right) - \frac{3}{4}(E_V + E_C)\ln\left(\frac{m_h}{m_e}\right)$

55. A silicon sample A is doped with 10^{18} atoms/cm^3 of Boron. Another sample B of identical dimensions is doped with 10^{18} atoms/cm^3 of Phosphorus. The ratio of electron to hole mobility is 3. The ratio of conductivity of the sample A to B is:

(a) 3 (b) 1/3 (c) 2/3 (d) 3/2

56. N-type silicon is obtained by doping silicon with:

(a) Germanium (b) Aluminium (c) Boron (d) Phosphorus

57. The band-gap of silicon at 300 K is:

(a) 1.36 eV (b) 1.10 eV (c) 0.80 eV (d) 6.67 eV

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58. The intrinsic carrier density at 300 K is $1.5\times10^{10}/cm^3$, in silicon. For n-type silicon doped to 2.25×10^{15} atoms $/cm^3$, the equilibrium electron and hole densities are:
(a) $n=1.5\times10^{15}/cm^3$, $p=1.5\times10^{10}/cm^3$ (b) $n=1.5\times10^{10}/cm^3$, $p=2.25\times10^{15}/cm^3$
(c) $n=2.25\times10^{15}/cm^3$, $p=1.0\times10^{5}/cm^3$ (d) $n=1.5\times10^{10}/cm^3$, $p=1.5\times10^{10}/cm^3$

59. The drift velocity of electrons in silicon:
(a) Is proportional to the electric field for all values of electric field.
(b) Is independent of the electric field.
(c) Increases at low values of electric field and decreases at high values of electric field exhibiting negative differential resistance.
(d) Increases linearly with electric field at low values of electric field and gradually saturates at higher values of electric field.

60. A silicon sample is uniformly doped with 10^{16} phosphorous atoms/cm^3 and 2×10^{16} boron atoms/cm^3. If all the dopants are fully ionized, the material is:
(a) n-type with carrier concentration of $10^{16}/cm^3$
(b) p-type with carrier concentration of $10^{16}/cm^3$
(c) p-type with carrier concentration of $2\times10^{16}/cm^3$
(d) T_2-will get damaged and T_1 will be safe.

61. In a uniformly doped abrupt p-n junction, the doping level of n-side is four (4) times the doping level of the p-side. The ratio of the depletion layer widths is:
(a) 0.25 (b) 0.5 (c) 1.0 (d) 2.0

62. LED is a
(a) p-n diode (b) Thermistor (c) Gate (d) Transistor

63. As per Hall effect, if any specimen carrying a current I is placed in a transverse magnetic field B, then an electric field E is induced in the specimen in the direction.
(a) Parallel to I (b) Perpendicular to B and parallel to I
(c) Parallel to I and B (d) Perpendicular to both I and B.

64. The doping concentration on the n-side of a p-n junction diode is enhanced. Which one of the following will get affected?
(a) Width of the depletion region on n-side.
(b) Width of the depletion region on p-side.
(c) Width of the depletion region on both sides.
(d) No change in width of depletion regions

65. Which one of the following expressions may be used to correctly describe the temperature(T) variation of the intrinsic carrier density (n_i) of a semiconductor?
(a) $n_i(T)=(A/T)\exp(-E_g/kT^2)$ (b) $n_i(T)=A(E_g/kT)^{10}$
(c) $n_i(T)=A\exp(-E_g/2kT)$ (d) $n_i(T)=AT^{3/2}\exp(-E_g/2kT)$

66. An intrinsic semiconductor (intrinsic electron density = 10^{16} m^{-3}) is doped with donors to a level of 10^{22} m^{-3}. What is the hole density assuming all donors to the ionized?
(a) 10^7 m^{-3} (b) 10^8 m^{-3} (c) 10^{10} m^{-3} (d) 10^6 m^{-3}.

67. Consider the following statements in respect of graphite:
1. It has the three coplanar covalent bonds.
2. It has good electrical and thermal conductivity. (Poor thermal conductivity)
3. Sheets of graphite are held together by van der waals interaction.
Which of the statements given above are correct?
(a) 1, 2 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1 and 3

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68. The free electron density in a conductor is $(1/1.6)\times10^{22}$ cm^{-3}. The electron mobility is 10 cm^2/V s. What is the value of its resistivity?
(a) 10^{-4} Wm (b) 1.6×10^{-2} Wm (c) 10^{-4} Ωcm (d) 10^{-4} Ω cm^{-1}

69. Which one of the following is the correct relationship between the band gap of a material used in a photo detector and the energy of the incident photon?
(a) $E_g \geq hc/\lambda$ (b) $h\upsilon > E_g$ (c) $h\upsilon \geq E_g$ (d) $h\upsilon \leq E_g$

70. Two pure specimen of a semiconductor material are taken. One is doped with 10^{18} cm^{-3} number of donors and the other is doped with 10^{16} cm^{-3} number of acceptors. The minority carrier density in the first specimen is 10^7 cm^{-3}. What is the minority carrier density in the other specimen?
(a) 10^{16} cm^{-3} (b) 10^{27} cm^{-3} (c) 10^{18} cm^{-3} (d) 10^9 cm^{-3}

71. A copper wire is 1 metre long and has a uniform cross-section of 0.1 mm^2. The resistance of the wire at room temperature is 0.171 ohm. What is the resistivity of the material?
(a) 1.71×10^{-6} Ω.m (b) 1.71×10^{-7} Ω.m (c) 1.71×10^{-8} Ω.m (d) 1.71×10^{-9} Ω.m

72. A conductor carries a current of 4A and if magnitude of charge of an electron $e = 1.6\times10^{-19}$ coulomb, then th number of electrons which flow past the cross section per second is:
(a) 2.5×10^{19} (b) 1.6×10^{19} (c) 6.04×10^{19} (d) 0.4×10^{19}

73. In an extrinsic semiconductor the Hall coefficient R_H.
(a) Increases with increase of temperature
(b) Decreaes with increase of temperature
(c) Is independent of the change of temperature
(d) Changes with the change of magnetic field.

74. As the Fermi energy of silver is 8.8×10^{-19} joule, the velocity of the fastest electron in the silver at 0 K. (Given: Rest mass of electron = 9.1×10^{-31} kg) is:
(a) 3.33×10^5 m/s (b) 4.40×10^7 m/s (c) 1.39×10^6 m/s (d) 3×10^8 m/s

75. Which of the following statements related to the Hall effect?
1. A potential difference is developed across a current-carrying metal strip when the strip is placed in a transverse magnetic field.
2. The Hall effect is very weak in metals but is large in semiconductors
3. The Hall effect is very weak in semiconductors but is large in metals.
4. It is applied in the measurement of the magnetic field intensity.
Select the correct answer using the code given below:
(a) 1, 2 and 3 (b) 2 and 4 (c) 1, 3 and 4 (d) 1, 2 and 4

76. Which of the following elements act as donor impurities?
1. Gold 2. Phosphorus 3. Boron 4. Antiomony
5. Arsenic 6. Indium.
Select the corrent answer using the codes given below:
(a) 1, 2 and 3 (b) 1, , 4 and 5 (c) 3, 4, 5 and 6 (d) 2, 4 and 5

77. Germanium and silicon photo-sensors have their maximum spectral response in the
(a) Infrared region (b) Ultraviolet region
(c) Visible region (d) X-ray region

78. The conductivity of an intrinsic semicoductor is (symbols have the usual meanings) where e is electron charge
(a) Generally less than that of a doped semiconductor.
(b) Given by $\sigma_i = en_i(\mu_n - \mu_p)$
(c) Given by $\sigma_i = en_i(\mu_n + \mu_p)$
(d) Given by $\sigma_i = n_i(\mu_n + \mu_p)$

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79. Measurement of Hall effect coefficient in a semiconductor provides information on the
(a) Sign and mass of charge carriers (b) Mass and concentration of charge carriers
(c) Sign of charge carriers alone (d) Sign and concentration of charge carriers.

80. The temperature (T) dependence of magnetic susceptibility (χ) of a ferromagnetic substance with a Curie temperature (T_c) is given by

(a) $\frac{C}{T-T_c}$, for $T < T_c$ (b) $\frac{C}{T-T_c}$, for $T > T_c$

(c) $\frac{C}{T+T_c}$, for $T > T_c$ (d) $\frac{C}{T+T_c}$, for all temperature.

Common data Q.81 and Q.82:
The tight binding energy dispersion (E–k) relation for electrons in a one-dimensional array of atoms having lattice constant a and total length L is:

$$E = E_0 - \beta - 2\gamma\cos(ka)$$

Where E_0, β and γ are constants and k is the wave-vector.

81. The density of states of electrons (including spin degeneracy) in the band is given by

(a) $\frac{L}{\pi ya\sin(ka)}$ (b) $\frac{L}{2\pi ya\sin(ka)}$ (c) $\frac{L}{2\pi ya\cos(ka)}$ (d) $\frac{L}{\pi ya\cos(ka)}$

82. The effective mass of electrons in the band is given by

(a) $\frac{\hbar^2}{\gamma a^2\cos(ka)}$ (b) $\frac{\hbar^2}{2\gamma a^2\cos(ka)}$ (c) $\frac{\hbar^2}{\gamma a^2\sin(ka)}$ (d) $\frac{\hbar^2}{2\gamma a^2\cos(ka)}$

83. Light of wavelength 660 nm and power of 1 mW is incident on a semiconductor photodiode with an absorbing layer of thickness of (ln 4) μm .
A. If the absorption coefficient at this wavelength is 10^4 cm^{-1} and if 1% power is lost on reflection at the surface, the power absorbed will be
(a) 750 μW (b) 675 μW (c) 250 μW (d) 225 μW

B. The generated photo-current for a quantum efficiency of unity will be
(a) 360 μA (b) 400 μA (c) 133 μA (d) 120 μA

84. A narrow beam of X-rays with wavelength 1.5Å is reflected from an ionic crystal with an fcc lattice structure with a density of 3.32 g cm^{-3}. The molecular weight is 108 AMU (1 AMU= 1.66×10^{-24} g).
A. The lattice constant is:
(a) 6.00Å (b) 4.56Å (c) 4.00Å (d) 2.56Å
B. The sine of the angle corresponding to (111) reflection is:
(a) $\sqrt{3}/4$ (b) $\sqrt{3}/8$ (c) 1/4 (d) 1/8

85. A flux quantum (fluxoid) is approximately equal to 2×10^{-7} gauss-cm^2. A type II superconductor is placed in a small magnetic field, which is then slowly increased till the field starts penetrating the superconductor. The strength of the field at this point is $\frac{2}{\pi}\times10^5$ gauss

A. The penetration depth of this superconductor is
(a) 100Å (b) 110Å (c) 1000Å (d) 314 Å

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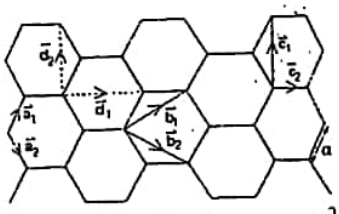
B. The applied field is further increased till superconductivity is completely destroyed. The strength of the field is now $\frac{8}{\pi}\times10^5$ gauss. The correlation length of the superconductor is:

(a) 20Å (b) 200Å (c) 628 Å (d) 2000Å

86. The two dimensional lattice of graphene is an arrangement of Carbon atoms forming a honeycomb lattice of lattice spacing a, as shown below. The carbon atoms occupy the vertices.



A. The Wigner-Seitz cell has an area of

(a) $2a^2$ (b) $\frac{\sqrt{3}}{2}a^2$ (c) $6\sqrt{3}\,a^2$ (d) $\frac{3\sqrt{3}}{2}a^2$

B. The Bravais lattice for this array is a

(a) Rectangular lattice with basis vectors $\bar{d}_1$ and $\bar{d}_2$

(b) Rectangular lattice with basis vectors $\bar{c}_1$ and $\bar{c}_2$

(c) Hexagonal lattice with basis vectors $\bar{a}_1$ and $\bar{a}_2$

(d) Hexagonal lattice with basis vectors $\bar{b}_1$ and $\bar{b}_2$.

87. The solid phase of an element follows van der Waals bonding with iner-atomic potential $V(r)=-\frac{P}{r^6}+\frac{Q}{r^{12}}$, where P and Q are constants. The bond length can be expressed as

(a) $\left(\frac{2Q}{P}\right)^{-6}$ (b) $\left(\frac{Q}{P}\right)^{-6}$ (c) $\left(\frac{P}{2Q}\right)^{-6}$ (d) $\left(\frac{P}{Q}\right)^{-6}$

88. The total number of Cl^- ions in a unit cell of NaCl crystal is

(a) 4 (b) 2 (c) 8 (d) 10

89. If the distance between a Na ion and a chlorine ion in NaCl crystal is 0.28 nm, then the lattice parameter of the crystal is

(a) 0.14 nm (b) 0.8 nm (c) 56 Ao (d) 0.56 nm

90. At the equilibrium spacing of a diatomic molecule, the resultant force is

(a) zero (b) minimum (c) maximum (d) unity

91. The potential energy in the above said spacing is

(a) zero (b) minimum (c) maximum (d) unity

92. Which of the interatomic bonds are directional?

(a) covalent (b) metallic (c) ionic (d) van der Waals

93. The co-ordination number of Na^+ and Cl^- in the rock salt structure is respectively

(a) 8 and 6 (b) 6 and 8 (c) 6 and 6 (d) 4 and 4

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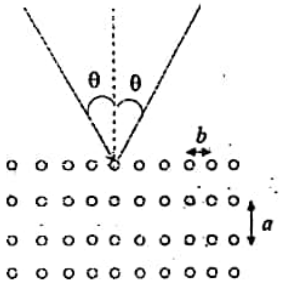
94. In a scanning tunnelling microscope, a fine Platinum needle is held close to a metallic surface in vacuum and electrons are allowed to tunnel across the tiny gap δ between the surface and the needle. The tunnelling current I is related to the gap δ, through positive constants a and b, as

(a) $I = a - b\delta$ (b) $I = a + b\delta$ (c) $\log I = a - b\delta$ (d) $\log I = a + b\delta$

95. A monochromatic beam of X-ray with wavelength λ is incident at an angle θ on a crystal with lattice spacing a and b as sketched in the figure below.

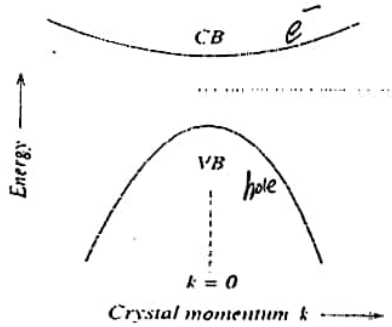


A condition for there to a maximum in the diffracted X-ray intensity is

(a) $2\sqrt{a^2+b^2}\sin\theta = \lambda$ (b) $2b\cos\theta = \lambda$

(c) $2a\cos\theta = \lambda$ (d) $(a+b)\sin\theta = \lambda$

96. Suppose the energy band of a certain pure crystalline solid is as shown in the figure below, where the energy (E) varies with crystal momentum (k) as $E \propto k^2$



At finte temperatures the bottom of the conduction band (CB) is partially filled with electrons (e) and the top of the valence band (VB) is partially filled holes (h). If an electric fields is applied to this solid, both e and h will start moving. If the time between collisions is the same for both e and h, then

(a) e and h will move with the same speed in opposite directions
(b) h will on an average achieve higher speed than e
(c) e will on an average achieve higher speed than h
(d) e and h will recombine and after a while there will be no flow of charges.

97. Metallic Copper is known to from cubic crystals and the lattice constant is measured from X-ray diffraction studies to be about 0.36nm. If the specific gravity of Copper is 8.96 and its atomic weight is 63.5, one can conclude that

(a) the crystals are of simple cubic type (b) the crystals are of b.c.c. type

(c) the crystals are of f.c.c. type (d) the crystals are a mixture of f.c.c. and b.c.c. types.

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98. The potencial of a diatomic molecule as a function of the distance r between the atoms is given by $V(r) = -\frac{a}{r^6} + \frac{b}{r^{12}}$. The value of the potential at equilibrium separation between the atoms is :

(a) $-4a^2/b$ (b) $-2a^2/b$ (c) $-a^2/2b$ (d) $-a^2/4b$

99. Assume that the free energy of a magnetic system has an expansion in the order parameter M of the form $F(M,T) = a(T-T_c)M^2 + bM^4 + cM^6$, with a, b and $c > 0$. As the temperature is lowered below T_c, the system undergoes a phase transition. The behaviour of the order parameter just below the transition, where $(T-T_c)$ is very small, is best described by

(a) $M \propto (T_c - T)^{-1/2}$ (b) $M \propto (T_c - T)^{1/2}$ (c) $M \propto (T_c - T)$ (d) $M \propto (T_c - T)^3$

100. The energy levels of electrons of mass 'm' and charge 'e' confined in an area A in the xy-plane with a uniform magnetic field B applied in the z-direction are given by $E_n = \left(n + \frac{1}{2}\right)\frac{eB\hbar}{mc}, n = 0,1,2....$ The degeneracy of each level is $\frac{eBA}{\hbar c}$. The lowest level is completely filled the other are empty. The fermi energy $\frac{\hbar^2 N}{2\pi mA}$, where N is the total number of electrons, is:

(a) coincident with the n = 0 level (b) coincident with the n = 1 level

(c) midway between the n = 0 and the n = 1 levels

(d) midway between the n = 1 and the n = 2 levels.

101. The excitation of a three-dimensional solid are bosonic in nature with their frequency ω and wave-number k are related by $\omega \propto k^2$ in the large wavelength limit. If the chemical potential is zero, the behaviour of the specific heat of the system at low temperature is proportional to

(a) $T^{1/2}$ (b) T (c) $T^{3/2}$ (d) T^3

102. Monochromatic light of wavelength 660 nm and intensity 100 mW/cm^2 falls on a solar cell of area 30 cm^2. The conversion efficiency of the solar cell is 10%. If each coverted photon results in an electron-hole pair, what is the maximum circuit current supplied by the solar cell? (Take $h = 6.6\times10^{-34}\,J-s$, $c = 3\times10^8\,m/s$ and $e = 1.6\times10^{-19}\,C$).

(a) 160 mA (b) 320 mA (c) 1600 mA (d) 3200 mA

103. The magnetization M of a system in equilibrium at temperature T is given by the equation $M = \tanh\left(M/T\right)$, where all quantities are in dimensionless units. This system will show

(a) a first order phase transition at T = 1 (b) a second order phase transition at T = 1

(c) no phase transition at any T (d) a second order phase transition at $T = 1/2$.

104. The basis vectors of a lattice are $2\hat{i}, \hat{i}+2\hat{j}$ and $\hat{k}$. The basis vectors of the reciprocal lattice are

(a) $\frac{2}{\pi}(\hat{i}+\hat{j}), \frac{2}{\pi}\hat{j}$ and $\frac{2}{\pi}\hat{k}$ (b) $\pi(2\hat{i}-\hat{j}), \pi\hat{j}$ and $4\pi\hat{k}$

(c) $\frac{\pi}{2}(2\hat{i}-\hat{j}), \pi\hat{j}$ and $2\pi\hat{k}$ (d) $2\pi\hat{i}, \pi(\hat{i}+2\hat{j})$, and $\pi\hat{k}$

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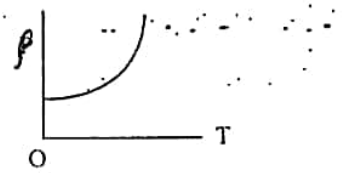
105. The number of phonon branch in graphite, with four atoms in the primitive cell, is
(a) 8, out of which two are acoustic, the rest optical
(b) 9, out of which three are acoustic , the rest optical
(c) 12, out of which three are acoustic, the rest optical
(d) 12, out of which two are acoustic, the rest optical

106. The nature of the interaction that gives rise to the van der Waals force in a molecular crystal is
(a) dipolar (b) nuclear (c) magnetic (d) quadrupolar

107. The experimental method used most frequently for detecting magnetic structure of solids is
(a) electron diffraction (b) neutron diffraction
(c) x-ray diffraction (d) photo-emission spectroscopy

108. We know that the allowed wave vectors for phonons in a crystal have discrete values. This is a consequence of
(a) quantization of phonons (b) periodic boundary conditions
(c) uncertainty principle (d) periodic structure of the lattice

109. The temperature dependence of the electrical resistivity ρ of a material is shown in the plot below. This material is a



(a) insulator (b) semiconductor (c) normal metal (d) superconductor

110. The specific heat of a normal metal at low temperatures is dominated by the contribution of
(a) conduction electrons (b) acoustic phonons
(c) core electrons (d) optical phonons

111. The Fermi level in an intrinsic semiconductor at zero temperature lies
(a) in the conduction band (b) at the top of the valence band
(c) at the bottom of the conduction band
(d) in the energy gap between the valence and the conduction bands

112. Let ξ and λ denote the coherence length and the penetration depth of a superconductor. For a type-I, superconductor
(a) $\xi < \lambda$ (b) $\xi > \lambda$ (c) $\xi = \lambda$ (d) $\lambda = 0$

113. A KCl crystal grown in an environment containing some $CaCl_2$ will have
(a) excess positive charge (b) higher density
(c) lower ionic conductivity (d) more lattice vacancies.

114. According to the Debye model, the internal energy of a solid a at temperature T close to absolute zero varies as
(a) T^2 (b) T^4 (c) T^3 (d) T

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115. In a period potential given by $V(\vec{r}) = V(\vec{r} + \vec{R})$, where $\vec{R}$ is the lattice vector, the eigenstates of the Hamiltonian $H = \frac{-\hbar^2}{2m}\nabla^2 + V(\vec{r})$ are $\psi_k(\vec{r}) = e^{i\vec{k}.\vec{r}} u_{\vec{k}}(\vec{r})$, where

(a) $u_{\vec{k}}(\vec{r}) = e^{i\vec{k}.\vec{R}} \left(\vec{k} \neq \vec{k}'\right)$ (b) $u_{\vec{k}}(\vec{r}) = e^{i\vec{k}.\vec{R}}\, u_{\vec{k}}\left(\vec{r} + \frac{\vec{R}}{3}\right)$

(c) $u_{\vec{k}}(\vec{r}) = u_{\vec{k}}\left(\vec{r} + \frac{\vec{R}}{2}\right)$ (d) $u_{\vec{k}}(\vec{r}) = u_{\vec{k}}\left(\vec{r} + \vec{R}\right)$

116. The magnetic susceptibility of a type I superconductor at a temperature T below the transition temperature T_c

(a) increases linearly from a negative value to zero as temperature increases from 0 to T_c

(b) decreases linearly from a positive value to zero as temperature increases from 0 to T_c

(c) is negative and constant at all T (d) is positive and constant at all T

117. In an intrinsic semiconductor, as the temperature increases the conductivity σ, electron concentration n, and mobility μ vary as follows:

(a) σ decreases, n increases and μ decreases (b) σ decreases, n is unaffected and μ decreases

(c) σ increases, n increases and μ decreases (d) σ increases, n increases and μ is unaffected

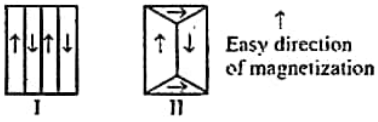
118. The value of a primitive unit cell defined by axes $\left(\hat{k} + \hat{i}\right)$Å, $\left(\hat{i} + \hat{j}\right)$Å, $\left(\hat{j} + \hat{k}\right)$Å, is

(a) $1Å^3$ (b) $3Å^3$ (c) $2Å^3$ (d) $4Å^3$

119. In the Hall effect the sign of the Hall voltage depends upon the carrier concentration (n,p) and mobility $(\mu_n\ \mu_p)$ of electrons and holes, respectively. The Hall voltage in intrinsic and n-type semiconductors is negative because

(a) $n\mu_n > p\mu_p$ (b) $n > p, \mu_n < \mu_p$ (c) $n > p, \mu_n = \mu_p$ (d) $n = p, \mu_n > \mu_p$

120. Two possible domain structures (I and II) with an easy direction of magnetization (along the arrow) for a ferromagnetic material are shown. E_{ms} and E_{ca} are magnetostatic and crystalline anisotropy energy of the domain structure. Which of the following statements is correct?



(a) $E_{ms}(I) < E_{ms}(II)$ (b) $E_{ca}(I) > E_{ca}(II)$

(c) $E_{ms}(I) < E_{ms}(II)$, $E_{ca}(I) < E_{ca}(II)$ (d) $E_{ms}(I) > E_{ms}(II)$, $E_{ca}(I) < E_{ca}(II)$

121. The Miller indices of a plane passing through the points $3\hat{a}$, $4\hat{b}$ and $5\hat{c}$, where $\hat{a}$, $\hat{b}$ and $\hat{c}$, are lattice vectors are

(a) (12, 15, 20) (b) (20, 15, 12) (c) (5, 4, 3) (d) (3, 4, 5)

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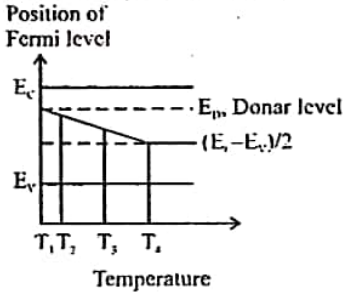
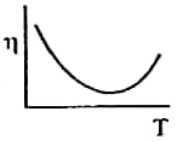
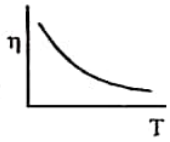
122. In the following figure, the position of the Fermi level is shown as a function of temperature along with the band diagram of an n-type semiconductor. The temperature at which 50% of the donor atoms are ionized is

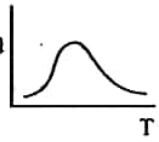


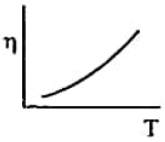
(a) T_3 (b) T_1 (c) T_4 (d) T_2

123. Which of the following figures represents the temperature dependence of the thermal conductivity η of a solid according to the Drude model.

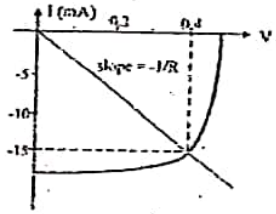
(a) 

(b) 

(c) 

(d) 

124. The I-V characteristics of a solar cell of dimension 1 cm ×1 cm illuminated with light of intensity 600 Wm^{-2} are shown in the figure. If the cell is used to drive a load R (see the load line in the figure) the efficiency of the solar cell is:



(a) 1% (b) 5% (c) 20% (d) 10%

125. In an experiment to measure the Hall co-efficient of a particular sample, the generated Hall voltage was found to be too small to measure. To improve the measurement, you would
(a) Increase the magnetic field (b) Increase the temperature of the sample
(c) Use a longer and thinner sample (d) Use a shorter and thicker sample.

126. When the sample is heated the X-ray diffraction pattern of a powder changes as follows:
(a) The line spacing decreases and line intensity increases
(b) The line spacing and line intensity both increases
(c) The line spacing increases and line intensity decreases
(d) The line spacing and line intensity both decrease

127. Let $\Phi(\bar{q}) = \int d\bar{r}\, e^{iq.\bar{r}} V(\bar{r})\, q \neq 0$, where $V(\bar{r})$ is the potential seen by an electron in a crystal lattice. If $\bar{G}$ is a reciprocal lattice vector, then $\Phi(\bar{q})$ is nonzero,

(a) only if $\bar{q} = \bar{G}$ (b) for $\bar{q} = \frac{1}{2}\bar{G}$ (c) for all $\bar{q}$ (d) for all $\bar{q}$ within the Brillouin zone.

128. In the continuum model of an elastic solid, the frequency of sound waves
(a) is constant in some directions and proportional to the wave-vector in other directions
(b) is proportional to the square of the wave-vector
(c) is a constant independent of the wave-vector
(d) is proportional to the wave-vector in all directions.

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129. The number of acoustic phonon branches in a three-dimensional crystal with 3 atoms per primitive cell is
(a) 6 (b) 9 (c) 3 (d) 12

130. The most suitable experimental method for studying the dispersion relation of phonons is
(a) X-ray diffraction (b) elastic scattering of neutorns
(c) inelastic scattering of thermal neutrons (d) photo-electron emission.

131. For Li metal, the resistivity at 77K is $1.01\ \mu\Omega-cm$ and that at 273K is $8.57\ \mu\Omega-cm$. The ratio of the mean collision times, $\frac{\tau_{77}}{\tau_{273}}$ is approximately,
(a) 3 (b) 1/9 (c) 9 (d) 1/3

132. The real part of the ac conductivity of a metal at a large frequency $\omega(\omega\tau >> 1, \tau = \text{mean collision time})$.
(a) increases as ω (b) decreases $\frac{1}{\omega^2}$
(c) becomes independent of ω (d) varies as $\sqrt{\omega}$

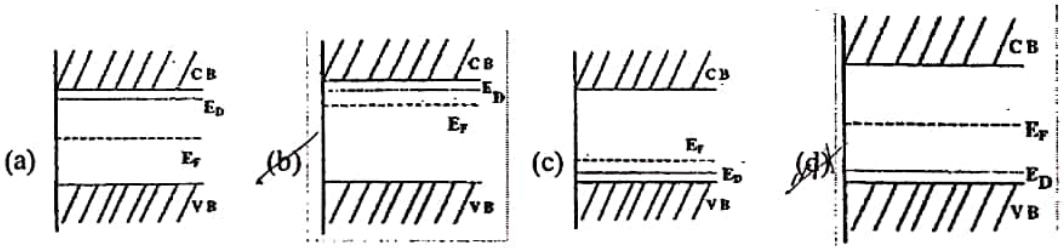
133. The (Pauli) paramagnetic susceptibility of a metal at a low temperature T is
(a) proportional to $\frac{1}{T}$ (b) independent of T
(c) proportional T^2 (d) proportional to T

134. The isotope effect in superconductors says that the critical temperature
(a) increases as the isotopic mass increases (b) decreases as the isotopic mass increases
(c) increases linearly with the isotopic mass (d) decreases linearly with the isotopic mass.

135. For an ideal Fermi gas in three dimensions, the electron velocity V_F at he Fermi surface is related to electron concentration n as,
(a) $V_F \propto n^{2/3}$ (b) $V_F \propto n$ (c) $V_F \propto n^{1/2}$ (d) $V_F \propto n^{1/3}$

136. A Ge semiconductor is doped with acceptor impurity concentration of 10^{15} atoms/cm^3. For the given hole mobility of 1800 $cm^2/V-s$, the resistivity of this material is:
(a) 0.288 Ω cm (b) 0.694 Ω cm (c) 3.472 Ω cm (d) 6.944 Ω cm

137. Identify the CORRECT energy band diagram for silicon doped with Arsenic. Here CB, VB, E_D and E_F conduction band, valence band, impurity level and Fermi level, respectively.



138. Which one of the following CANNOT be explained by considering a harmonic approximation for the lattice vibrations in solids ?
(a) Debye's T^3 law (b) Dulong petit's law
(c) Optical baranches in lattices (d) Thermal expansion

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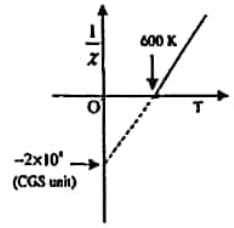
139. Inverse susceptibility $(1/\chi)$ as a function of temperature, T for a material undergoing paramagnetic to ferromagnetic transition is given in the figure, where O is the origin. the values of the Curie constant, C and the Weiss molecular field constant, λ, in CGS units, are



(a) $C = 5\times10^{-5}, \lambda = 3\times10^{-2}$ (b) $C = 3\times10^{-2}, \lambda = 5\times10^{-5}$

(c) $C = 3\times10^{-2}, \lambda = 2\times10^{4}$ (d) $C = 2\times10^{4}, \lambda = 3\times10^{-2}$

140. A simple cubic crystal with lattice parameter a_c undergoes transition into a tetragonal structure with lattice parameter $a_t = b_t = \sqrt{2}\, a_c$ and $c_t = 2a_c$, below a certain temperature. The ratio of the interplanar spacings of (101) planes for the cubic and the tetragonal structure is

(a) $\sqrt{\frac{1}{6}}$ (b) $\frac{1}{6}$ (c) $\sqrt{\frac{3}{8}}$ (d) $\frac{3}{8}$

Common data for Q. 141 and Q. 142

The dispersion relation for a one dimensional monatomic crystal with lattice spacing a, which interacts via nearest neighbour harmonic potential is given by $\omega = A\left|\sin\frac{Ka}{2}\right|$, where A is a constant of a appropriate unit.

141. The group velocity at the boundary of the first Brillouin zone is

(a) 0 (b) 1 (c) $\sqrt{\frac{Aa^2}{2}}$ (d) $\frac{1}{2}\sqrt{\frac{Aa^2}{2}}$

142. The force constant between the nearest neighbour of the lattice is (M is the mass of the atom)

(a) $\frac{MA^2}{4}$ (b) $\frac{MA^2}{2}$ (c) MA^2 (d) $2MA^2$

143. A beam of x-rays is incident on a BCC crystal. If the difference between the incident and the scattered wave vectors is $\vec{K} = h\hat{x} + k\hat{y} + \ell\hat{z}$ where $\hat{x}, \hat{y}, \hat{z}$ are the unit vectors of the associate cubic lattice, the necessary condition for the scattered beam to given a Laue maximum is

(a) h + k + l = even (b) h = k = 1 (c) h, k, l are all distinct (d) h + k + l = odd

144. The Dulong Petit law fails near room temperature (300 K) for many light elements (such as boron and beryllium) because their Debye temperature is

(a) $\gg$ 300 K (b) ~ 300 K (c) $\ll$ 300 K (d) 0 K

145. the second order maximum in the diffraction of X-rays of 0.20 nanometer wavelength from a simple cubic crystal is found to occur at an angle of thirty degrees with respect to the crystal plane. The distance between the lattice planes is

(a) 1 Angstrom (b) 2 Angstroms (c) 4 Angstroms (d) 8 Angstroms

146. The net charge of an n-type semiconductor is

(a) positive (b) zero (c) negative (d) dependent on the dopant density

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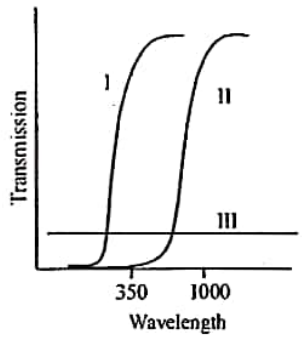
147. An LED operates at 1.5 V and 5 mA in forward bias. Assuming an 80% external efficiency of the LED, how many photons are emitted per second?

(a) 5.0×10^{16} (b) 1.5×10^{16} (c) 0.8×10^{16} (d) 2.5×10^{16}

148. The experimentally measured transmission spectra of metal, insulator and semiconductor thin films are shown in the figure. It can be inferred that I, II and III correspond respectively, to



(a) insulator, semiconductor and metal (b) semiconductor, metal and insulator
(c) metal, semiconductor and insulator (d) insulator, metal and semiconductor

149. The magnetization M of a ferromagnet, as a function of the temperature T and the magnetic field H, is described by the equaltion $M = \tanh\left(\frac{T_c}{T}M + \frac{H}{T}\right)$. In these units, the zero-field magnetic susceptibility in terms of $M(0) = M(H=0)$ is given by

(a) $\frac{1-M^2(0)}{T-T_c(1-M^2(0))}$ (b) $\frac{1-M^2(0)}{T-T_c}$ (c) $\frac{1-M^2(0)}{T+T_c}$ (d) $\frac{1-M^2(0)}{T}$

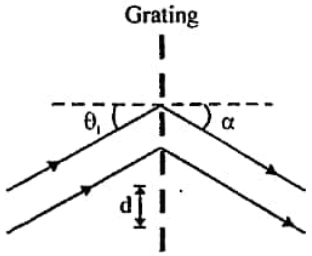
150. The energy required to create a lattice vacancy in a crystal is equal to 1 eV. The ratio of the number densities of vacancies $n(1200K)/n(300K)$, when the crystal is at equilibrium at 1200K and 300K, respectively is approximately

(a) exp(–30) (b) exp(–15) (c) exp(15) (d) exp(30)

151. The dispersion relation of phonons in a solid is given by $\omega^2(k) = \omega_0^2\left(3-\cos k_x a-\cos k_y a-\cos k_z a\right)$ The velocity of the phonons at large wavelenght is

(a) $\omega_0 a/\sqrt{3}$ (b) $\omega_0 a$ (c) $\sqrt{3}\omega_0 a$ (d) $\omega_0 a/\sqrt{2}$

152. A parallel beam of light of wavelength λ is incident on a transmission grating with groove spacing d, at an angle θ_i, as shown in the figure on the left. The plane of incidence is normal to the grooves. After diffraction, the transmitted beam is seen to be at an angle α relative to the normal. Which of the following conditions must be satisfied for this to happen?



(a) $d(\sin\theta_i - \sin\alpha) = n\lambda$ (b) $2d\sin(\theta_i - \alpha) = n\lambda$
(c) $d(\sin\theta_i + \sin\alpha) = n\lambda$ (d) $2d(\alpha + \theta_i) = n\lambda$

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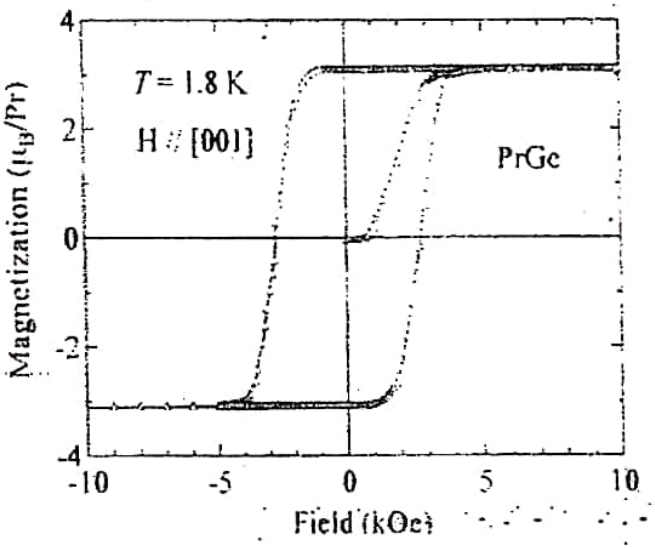
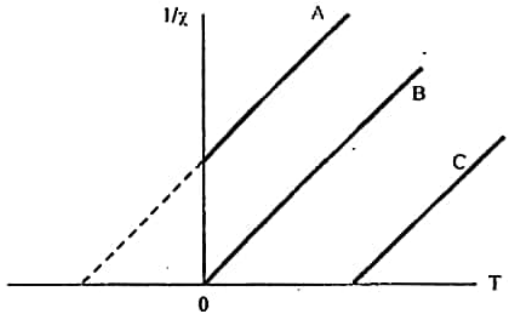
153. The Curie temperature of a single crystal of PrGe is known to be 41 K. The magnetization data of this sample is measured at 1.8K for the magnetic field applied parallel to the [001] direction is shown in the figure on the left. At a temperature of 38 K, the hysteresis loop in the figure will



(a) Have the same width
(b) decrease in width
(c) increase in width
(d) shrink to a line.

154. The magnetic susceptibility χ of three samples A, B and C, is measured as a function of their absolute temperature T, leading to teh graphs shown below.



From these graphs, the magnetic nature of the samples can be inferred to be

(a) A:anti-ferromagnet B: paramagnet C: ferromagnet
(b) A:diamagnet B: paramagnet C: anti-ferromagnet
(c) A:paramagnet B: anti-ferromagnet C: ferromagnet
(d) A:anti-ferromagnet B: diamagnet C: paramagnet.

155. The radius of the Fermi sphere of free electrons in a monovalent metal with an fcc structure, in which the volume of the unit cell is a^3, is

(a) $\left(\frac{12\pi^2}{a^3}\right)^{1/3}$ (b) $\left(\frac{3\pi^2}{a^3}\right)^{1/3}$ (c) $\left(\frac{\pi^2}{a^3}\right)^{1/3}$ (d) $\frac{1}{a}$

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156. A magnetic field sensor based on the Hall effect is to be fabricated by implanting. As into a Si film of thickness 1 μm. The specifications require a magnetic field sensitivity of 500 mV/Tesla at an excitation current of 1 mA. The implanation dose is to be adjusted such that the average carrier density, after activation, is

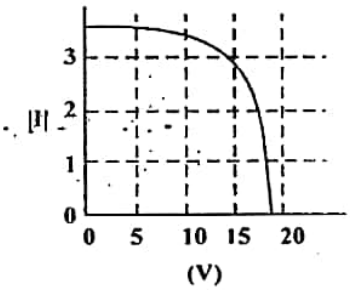
(a) $1.25\times10^{26}\ m^{-3}$ (b) $1.25\times10^{22}\ m^{-3}$ (c) $4.1\times10^{21}\ m^{-3}$ (d) $4.1\times10^{20}\ m^{-3}$

157. The free energy difference between the superconducting and the normal states of a material is given by

$\Delta F = F_S - F_N = \alpha|\psi|^2 + \frac{\beta}{2}|\psi|^4$, where ψ is an order parameter and α and β are constants such that $\alpha > 0$ in the normal and $\alpha < 0$ in the superconducting state, while $\beta > 0$ always. The minimum value of ΔF in the superconducting state is

(a) $-\alpha^2/\beta$ (b) $-\alpha^2/2\beta$ (c) $-3\alpha^2/2\beta$ (d) $-5\alpha^2/2\beta$

158. The output characteristics of a solar panel at a certain level of irradiance is shown in the figure below.



If the solar cell is to power a load of 5 Ω, the power drawn by the load is:

(a) 97W (b) 73 W (c) 50 W (d) 45 W

159. In a band structure calculation, the dispersion relation for electrons is found to be

$$\varepsilon_k = \beta\left(\cos k_x a + \cos k_y a + \cos k_z a\right)$$

where β is a constant and a is the lattice constant. The effective mass at the boundary of the first Brillioun zene is

(a) $\frac{2\hbar^2}{5\beta a^2}$ (b) $\frac{4\hbar^2}{5\beta a^2}$ (c) $\frac{\hbar^2}{2\beta a^2}$ (d) $\frac{\hbar^2}{3\beta a^2}$

160. A phosphorous doped silicon semiconductor (doping density: $10^{17}/cm^3$) is heated from 100°C to 200°C. Which one of the following statements is CORRECT?

(a) Position of Fermi level moves towards conduction band
(b) Position of dopant level moves towards conduction band
(c) Position of Fermi level moves towards middle of energy gap
(d) Position of dopant level moves towards middle of energy gap

161. Considering the BCS theory of superconductors, which one of the following statements is NOT CORRECT? (h is the Planck's constant and e is the electronic charge)

(a) Presence of energy gap at temperatures below the critical temperature
(b) Different critical temperatures for isotopes
(c) Quantization of magnetic flux in superconducting ring in the unit of $\left(\frac{h}{e}\right)$
(d) Presence of Meissner effect

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162. **Group-I** contains elementary excitations in solids. **Group-II** gives the associated fields with these excitations. MATCH the excitations with their associated field and select your answer as per codes given below.

Group-I		Group-II
(P) phonon	(i)	photon + lattice vibration
(Q) plasmon	(ii)	electron + elastic deformation
(R) polaron	(iii)	collective electron oscillations
(S) polariton	(iv)	elastic wave

Codes:

(a) (P–iv), (Q-iii), (R-i), (S-ii)
(b) (P–iv), (Q-iii), (R-ii), (S-i)
(c) (P–i), (Q-iii), (R-ii), (S-iv)
(d) (P–iii), (Q-iv), (R-ii), (S-i)

163. A lattice has the following primitive vectors (in A): $= \vec{a} = 2(\hat{j}+\hat{k}), \vec{b} = 2(\hat{k}+\hat{i}), \vec{c} = 2(\hat{i}+\hat{j})$. The reciprocal lattice corresponding to the above lattice is

(a) BCC lattice with cube edge of $\left(\frac{\pi}{2}\right)A^{-1}$
(b) BCC lattice with cube edge of $(2\pi)A^{-1}$
(c) FCC lattice with cube edge of $\left(\frac{\pi}{2}\right)A^{-1}$
(d) FCC lattice with cube edge of $(2\pi)A^{-1}$

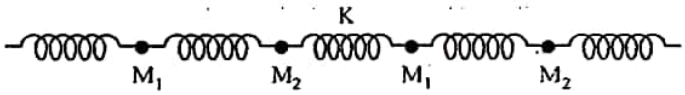
164. The total energy of an ionic solid is given by an expression $E = -\frac{\alpha e^2}{4\pi\varepsilon_0 r} + \frac{B}{r^9}$ where α is Madelung constant, r is the distance between the nearest neighbours in the crystal and B is a constant. If r_0 is the equilibrium separation between the nearest neighbours then the value of B is

(a) $\frac{\alpha e^2 r_0^8}{36\pi\epsilon_0}$
(b) $\frac{\alpha e^2 r_0^8}{4\pi\epsilon_0}$
(c) $\frac{2\alpha e^2 r_0^{10}}{9\pi\epsilon_0}$
(d) $\frac{\alpha e^2 r_0^{10}}{36\pi\epsilon_0}$

165. Using the frequency-dependent Drude formula, what is the effective kinetic inductance of a metallic wire that is to be used as a transmission line? [In the following, the electron mass is m, density of electrons is n, and the length and cross-sectional area of the wire are ℓ and A respectively]

(1) $mA/(ne^2\ell)$
(2) zero
(3) $m\ell/(ne^2A)$
(4) $m\sqrt{A}/(ne^2\ell^2)$

166. The phonon dispersion for the following one-dimensional diatomic lattice with masses M_1 and M_2 (as shown in the figure)



is given by

$$\omega^2(q) = K\left(\frac{1}{M_1}+\frac{1}{M_2}\right)\left[1 \pm \sqrt{1-\frac{4M_1M_2}{(M_1+M_2)^2}\sin^2\left(\frac{qa}{2}\right)}\right]$$

where a is the lattice parameter and K is spring constant. The velocity of sound is

(1) $\sqrt{\frac{K(M_1+M_2)}{2M_1M_2}}a$
(2) $\sqrt{\frac{K}{2(M_1+M_2)}}a$
(3) $\sqrt{\frac{K(M_1+M_2)}{M_1M_2}}a$
(4) $\sqrt{\frac{KM_1M_1}{2(M_1+M_2)^3}}a$

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167. The electron dispersion relation for a one-dimensional metal is given by

$$\varepsilon_k = 2\varepsilon_0\left[\sin^2\frac{ka}{2} - \frac{1}{6}\sin^2 ka\right]$$

where k is the momentum, a is the lattice constant, ε_0 is a constant having dimensions of energy and $|ka| \le \pi$. If the average number of electrons per atom in the conduction band is 1/3, then the Fermi energy is

(1) $\varepsilon_0/4$ (2) ε_0 (3) $2\varepsilon_0/3$ (4) $5\varepsilon_0/3$

168. Which one of the following diffraction techniques has most surface sensitivity?
(a) X-ray (b) Electron (b) Neutron (d) Optical

169. The inter-planar spacing for (110) plane of a monoatomic FCC crystal of lattice constant 2Å is
(a) 1/2Å (b) 2Å (c) $\sqrt{2}$ Å (d) $\sqrt{3}$ Å

170. Which one of the following diffraction peaks will be absent in a powder diffraction pattern for BCC-crystalline powder such as Fe
(a) (110) (b) (111) (c) (200) (d) (211)

171. The position of an X-ray diffraction peak may be shifted with respect to the peak of a perfect crystal due to
(a) homogenous strain (b) inhomogeneous strain (Broadening) (c) small unstrained crystallites
(d) inhomogeneously strained nano-sized crystallites

172. The Burgers vector of a screw dislocation in an FCC crystal is $\frac{1}{2}[110]$. The possible line direction for the dislocation is
(a) [110] (b) [011] (c) [101] (d) [111]

173. A Schottky defect in Al_2O_3 involves
(a) an Al^{3+} vacancy and an Al^{3+} interstitial (b) an Al^{3+} vacancy and an O^{2-} interstitial
(c) an Al^{3+} vacancy and an O^{2-} vacancy (d) two Al^{3+} vacancies and three O^{2-} vacancies

Defect Related Questions

174. Which one of the following type of dislocations can cross-slip?
(a) Edge dislocations (b) Screw dislocations
(c) Mixed dislocations (d) Sessile dislocations

175. If the gap between ground state and excited state energy levels of electrons in an atom is 1eV. Estimate the wavelength of the light the atom will absorb? The value of the Planck's constant is 6.6×10^{-34} Js.
(a) 1 mm (b) 1.24 μm (c) 1.24 angstrom (d) 1cm

176. Which one of the statements about density of states is not true?
(a) Variation in the energy dependence of density of states is dimension independent.
(b) Variation in the energy dependence of density of states in 3D follows $E^{1/2}$
(c) Variation in the energy dependence of density of states in 2D follows E^0
(d) Variation in the energy dependence of density of states in 1D follows $E^{-1/2}$

177. By using X-ray diffraction one cannot obtain
(a) crystal structure (b) type of bonding (c) residual stress (d) grain size

178. Band gap of a semiconductor nanocrystal (keeping the same lattice structure)
(a) increases with decreasing size (b) decreases with decreasing size
(c) is same as that of bulk (d) is always materials dependent

179. The voltage required to produce 483.6 MHz through a Josephson junction is
(a) 1nV (b) 1μV (c) 1mV (d) 1V

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180. Structure of C_{60} fullerite is
(a) face center cubic (b) body center cubic (c) primitive cubic (d) base center cubic

181. The fraction of electrons excited across the energy gap of 0.7 eV in Ge, at room temperature is
(a) 0 (b) 1.4×10^{-6} (c) 1.6×10^{-8} (d) 1.03×10^{-12}

182. A typical semiconductor such as Ge is formed by what kind of bonds?
(a) Covalent (b) Ionic (c) van der Waals (d) Metallic

183. When a pentavalent impurity is added to Si, it becomes
(a) an insulator (b) a conductor
(c) an intrinsic semiconductor (d) an *n*-type semiconductor

184. An *n*-type semiconductor is
(a) positively charged (b) negatively charged
(c) electrically neutral (d) positively or negatively charged

185. When a pure semiconductor is heated, its resistance
(a) increases (b) decreases linearly
(c) decreases exponentially (d) remains the same

186. The transition temperature of a BCS superconductor with an average atomic mass of 199.5 is 4.185K. What is the transition temperature for an average atomic mass of 203.4?
(a) 4.185 (b) 4.145 (c) 4.226 (d) 4.105

187. A contribution to the heat capacity is large in magnetic materials at the temperature at which magnetic moments
(a) are ordered (b) are disordered
(c) are antiparallel to each other (d) become zero

188. A flat surface is covered with non-overlapping disks of same size: What is the largest fraction of the area that can be covered?
(a) $\frac{3}{\pi}$ (b) $\frac{5\pi}{6}$ (c) $\frac{6}{7}$ (d) $\frac{\pi}{2\sqrt{3}}$

189. A metal suffers a structural phase transition from face-centred cubic (FCC) to the simple cubic (SC) structure. It is observed that this phase transition does not involve any change of volume. The nearest neighbour distances d_{fc} and d_{sc} for the FCC and the SC structures respectively are in the ratio (d_{fc}/d_{sc}) [Given $2^{1/3} = 1.26$]
(a) 1.029 (b) 1.122 (c) 1.374 (d) 1.130

190. The energy of an electron in a band as a function of its wave vector **k** is given by $E(k) = E_0 - B(\cos k_x a + \cos k_y a + \cos k_z a)$, where E_0, B and a are constants. The effective mass of the electron near the bottom of the band is
(a) $\frac{2\hbar^2}{3Ba^2}$ (b) $\frac{\hbar^2}{3Ba^2}$ (c) $\frac{\hbar^2}{2Ba^2}$ (d) $\frac{\hbar^2}{Ba^2}$

191. A DC voltage V is applied across a Josephson junction between two superconductors with a phase difference ϕ_0. If I_0 and k are constants that depend on the properties of the junction, the current flowing through it has the form
(a) $I_0 \sin\left(\frac{2eVt}{\hbar} + \phi_0\right)$ (b) $kV \sin\left(\frac{2eVt}{\hbar} + \phi_0\right)$ (c) $kV \sin\phi_0$ (d) $I_0 \sin\phi_0 + kV$

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192. A sample of Si has electron and hole mobilities of 0.13 and 0.05 $m^2/V\text{-}s$ respectively at 300K. It is doped with P and Al with doping densities of $1.5 \times 10^{21}/m^3$ and $2.5 \times 10^{21}/m^3$ respectively. The conductivity of the doped Si sample at 300K is

(a) $8\Omega^{-1}m^{-1}$ (b) $32\Omega^{-1}m^{-1}$ (c) $20.8\Omega^{-1}m^{-1}$ (d) $83.2\Omega^{-1}m^{-1}$

193. A uniform linear monoatomic chain is modeled by a spring-mass system of masses m separated by nearest neighbor distance a and spring constant $m\omega_0^2$. The dispersion relation for this system is

(a) $\omega(k) = 2\omega_0\left(1-\cos\left(\frac{ka}{2}\right)\right)$ (b) $\omega(k) = 2\omega_0 \sin^2\left(\frac{ka}{2}\right)$

(c) $\omega(k) = 2\omega_0 \sin\left(\frac{ka}{2}\right)$ (c) $\omega(k) = 2\omega_0 \tan\left(\frac{ka}{2}\right)$

194. The physical phenomenon that cannot be used for memory storage applications is
(a) large variation in magnetoresistance as a function of applied magnetic field
(b) variation in magnetization of a ferromagnet as a function of applied magnetic field
(c) variation in polarization of a ferroelectric as a function of applied electric field
(d) variation in resistance of a metal as a function of applied electric field

195. A solid sample has the property that, when cooled below a certain temperature, it expels any small applied magnetic field from within the material. Which of the following best describes this sample in the cooled state?
(a) Paramagnet (b) Diamagnet (c) Ferromagnet (d) Anti-ferromagnet

196. In a low temperature experiment, the resistance of a sensor is used as a thermometer. In order to have better sensitivity in the range 100 mK to 1.0 K, which material would make the best sensor?
(a) Insulator (b) p-n junction (c) pure semiconductor (d) metal

197. For a pure germanium semiconductor cooled in liquid nitrogen, the average density of conduction electrons is about $n = 10^{12}$ per cm^3. At this temperature the electron and hole mobilities are equal and have the common value $\mu = 5.0\times10\ cm^2V^{-1}s^{-1}$. If a potential of 100V is applied across a 1 cm cube of this cooled germanium sample, the current observed can be estimated as
(a) 80 μA (b) 160 mA (c) 16 mA (d) 16 A

198. Melting temperature of strained nanoparticles having the same structure as that of bulk is
(a) higher than that of bulk (b) lower than that of bulk
(c) does not change (d) always 2/3 times that of bulk

199. What is the value of potential energy V, in a free electron gas theory of metals?
(a) A constant (b) Infinite
(c) It varies with the distance (d) zero

200. The lattice specific heat C of a crystalline solid can be obtained using the Dulong Petit model, Einstein model and Debye model. At low temperature $\hbar\omega >> K_BT$, which one of the following statements is true (a and A are constants)

(a) Dulong Petit: $C \propto \exp\left(\frac{-a}{T}\right)$; Einstein:C=.constant, Debye:$C \propto \left(\frac{T}{A}\right)^3$

(b) Dulong Petit:C = .constant; Einstein:$C \propto \left(\frac{T}{A}\right)^3$; Debye:$C \propto \exp\left(\frac{-a}{T}\right)$

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(c) Dulong Petit:C = .constant; Einstein:$C \propto \frac{e^{-a/T}}{T^2}$;Debye:$C \propto \left(\frac{T}{A}\right)^3$

(d) Dulong Petit:$C \propto \left(\frac{T}{A}\right)^3$; Einstein:$C \propto \frac{e^{-a/T}}{T^2}$;Debye:C=.constant

201. At low temperature the specific heat of insulating crystals varies as
(a) AT^3 (b) $BT + CT^3$
(c) D exp (E/T) (d) will not change with temperature.

202. Which of the following statement best explains why the specific heat of electrons in metals is much smaller than that expected in a non-interacting (free) electron gas model?

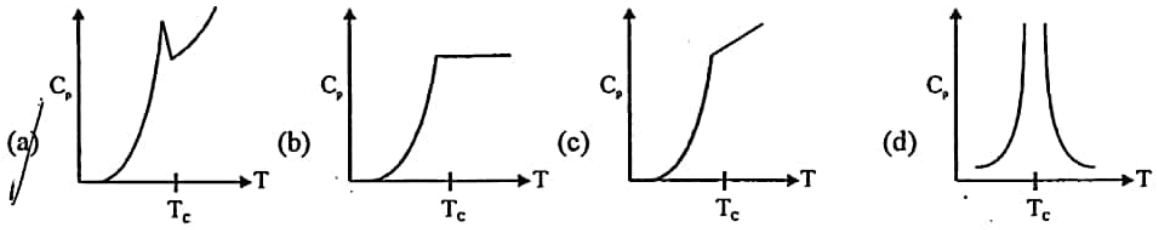
(a) The mass of electron is much smaller than that of the ions in the crystal.
(b) The Pauli exclusion principle restricts the number of electrons which can absorb thermal energy
(c) Electron spin can take only two different values.
(d) Electrons in a metal cannot be modelled as non-interacting.

203. An unpolarized light wave is incident from air on a glass surface at the Brewster angle. The angle between the reflected and the refracted wave is
(a) 0° (b) 45° (c) 90° (d) 120°

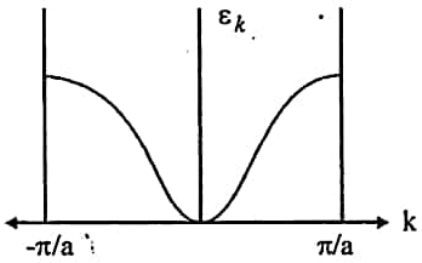
204. The Miller indices of a plane passing through the three points having coordinates (0, 0, 1), (1, 0, 0), $\left(\frac{1}{2}, \frac{1}{2}, \frac{1}{4}\right)$ are

(a) (2 1 2) (b) (1 1 1) (c) (1 2 1) (d) (2 1 1)

205. The plot of specific heat versus temperature across the superconducting transition temperature (T_C) is most appropriately represented by



206. The energy, ε_k for band electrons as a function of the wave vector, k in the first Brillouin zone $\left(-\frac{\pi}{a} \le k \le \frac{\pi}{a}\right)$ of a one dimensional monatomic lattice is shown as (a is latticec constant)



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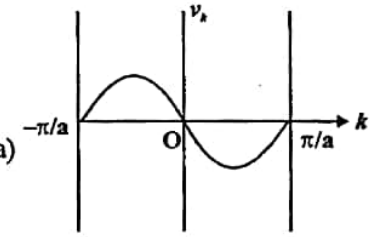
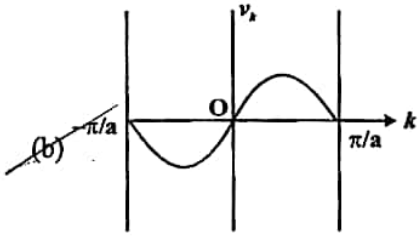
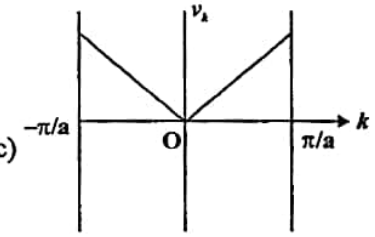
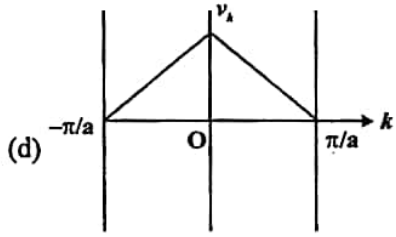
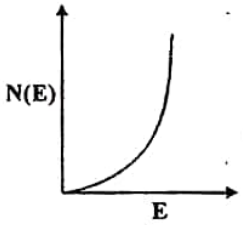
(a) 

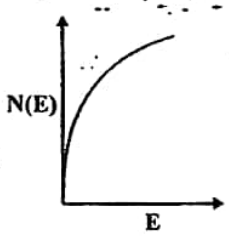
(b) 

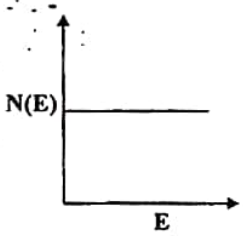
(c) 

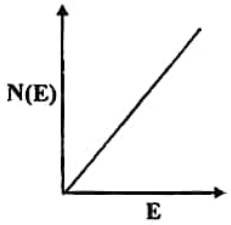
(d) 

207. For a free electron gas in two dimensions, the variation of the density of states, N(E) as a function of energy E, is the best represented by

(a) 

(b) 

(c) 

(d) 

208. For Nickel, the number density is 8×10^{23} atoms/cm^3 and electronic configuration is $1s^2\ 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$. The value of the saturation magnetization of Nickel in its ferromagnetic states is _____ $\times 10^9$ A/m.

(Given the value of Bohr magneton $\mu_B = 9.21\times10^{-21}\ Am^2$)

209. The donor concentration in a sample of n-type silicon is increased by a factor of 100. The shift in the position of the Fermi level at 300K, assuming the sample to be non degenerate is _____ meV.

$(k_BT = 25meV$ at 300K)

210. Neutrons moving with speed 10^3 m/s are used for the determination of crystal structure. If the Bragg angle for the first order diffraction is 30°, the interplanarspacing of the crystal is _____ Å.

(Given: $m_n = 1.675\times10^{-27}\ kg$, $h = 6.626\times10^{-34}\ Js$)

211. Consider an electron in a b.c.c. lattice with lattice constant a. A single particle wavefunction that satisfies the Bloch theorem will have the form $f(\vec{r})\exp(i\vec{k}\vec{r})$, with $f(\vec{r})$ being

(a) $1+\cos\left[\frac{2\pi}{a}(x+y-z)\right]+\cos\left[\frac{2\pi}{a}(-x+y+z)\right]+\cos\left[\frac{2\pi}{a}(x-y+z)\right]$ → BCC

(b) $1+\cos\left[\frac{2\pi}{a}(x+y)\right]+\cos\left[\frac{2\pi}{a}(y+z)\right]+\cos\left[\frac{2\pi}{a}(z+x)\right]$

(c) $1+\cos\left[\frac{\pi}{a}(x+y)\right]+\cos\left[\frac{\pi}{a}(y+z)\right]+\cos\left[\frac{\pi}{a}(z+x)\right]$ → BCC

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(d) $1+\cos\left[\frac{\pi}{a}(x+y-z)\right]+\cos\left[\frac{\pi}{a}(-x+y+z)\right]+\cos\left[\frac{\pi}{a}(x-y+z)\right]$

212. The dispersion relation for electrons in an f.c.c. crystal is given, in the tight binding approximation by

$$\varepsilon(k)=-4\varepsilon_0\left[\cos\frac{k_x a}{2}\cos\frac{k_y a}{2}+\cos\frac{k_y a}{2}\cos\frac{k_z a}{2}+\cos\frac{k_z a}{2}\cos\frac{k_x a}{2}\right]$$

where 'a' is the lattice constant and ε_0 is a constant with the dimension of energy. The x-component of the velocity of the electrons at $\left(\frac{\pi}{a},0,0\right)$ is

(a) $-\frac{2\varepsilon_0 a}{\hbar}$ (b) $\frac{2\varepsilon_0 a}{\hbar}$ (c) $-\frac{4\varepsilon_0 a}{\hbar}$ (d) $\frac{4\varepsilon_0 a}{\hbar}$

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Assignment-I: Solid State Physics [Answer Key]

1. (c)	2. (d)	3. (a)	4. (d)	5. (c)	6. (b,d)	7. (c)
8. (d)	9. (b)	10. (c)	11. (a)	12. (c)	13. (b)	14. (d)
15. (c)	16. (a)	17. (a)	18. (a)	19. (d)	20. (c)	21. (a)
22. (a)	23. (d)	24. (c)	25. (c)	26. (d)	27. (b)	28. (d)
29. (d)	30. (b)	31. (a)	32. (b)	33. (b)	34. (d)	35. (a)
36. (b)	37. (b)	38. (a)	39. (b)	40. (b)	41. (c)	42. (d)
43. (c)	44. (a)	45. (c)	46. (b)	47. (a)	48. (b)	49. (a)
50. (a)	51. (a)	52. (a)	53. (a)	54. (d)	55. (d)	56. (a)
57. (a)	58. (c)	59. (a)	60. (b)	61. (a)	62. (a)	63. (a)
64. (b)	65. (c)	66. (c)	67. (c)	68. (a)	69. (c)	70. (d)
71. (b)	72. (a)	73. (c)	74. (c)	75. (c)	76. (c)	77. (a)
78. (b)	79. (b)	80. (c)	81. (d)	82. (d)	83. (c)	84. (c)
85. (c)	86. (d)	87. (c)	88. (b)	89. (a)	90. (d)	91. (d)
92. (b)	93. (b)	94. (c)	95. (c)	96. (d)	97. (a)	98. (b)
99. (c)	100. (b)	101. (d)	102. (c)	103. (c)		

Assignment-II: Solid State Physics (Answer Key)

1. (d)	2. (a)	3. (b)	4. (b)	5. (a)	6. (d)	7. (c)
8. (c)	9. (b)	10. (d)	11. (b)	12. (b)	13. (b)	14. (b)
15. (a)	16. (d)	17. (a)	18. (b)	19. (b)	20. (a)	21. (b)
22. (b)	23. (d)	24. (b)	25. (b)	26. (a)	27. (d)	28. (d)
29. (d)	30. (b)	31. (c)	32. (d)	33. (c)	34. (a)	35. (b)
36. (b)	37. (c)	38. (b)	39. (a)	40. (b)	41. (a)	42. (a)
43. (c)	44. (d)	45. (d)	46. (c)	47. (c)	48. (c)	49. (c)
50. (b)	51. (a)	52. (a)	53. (a)	54. (c)	55. (d)	56. (b)
57. (c)	58. (d)	59. (b)	60. (a)	61. (a)	62. (d)	63. (a)
64. (d)	65. (c)	66. (c)	67. (c)	68. (b)	69. (d)	70. (b)
71. (a)	72. (c)	73. (c)	74. (c)	75. (d)	76. (a)	77. (c)
78. (d)	79. (d)	80. (b)	81. (b)	82. (b)	83_A(a)	83_B(b)
84_A(a)	84_B(b)	85_A(a)	85_B(a)	86_A(b)	86_B(c)	87. (c)
88. (a)	89. (d)	90. (a)	91. (b)	92. (a)	93. (c)	94. (c)
95. (c)	96. (b)	97. (c)	98. (d)	99. (b)	100. (c)	101. (c)
102. (a)	103. (b)	104. (c)	105. (a)	106. (a)	107. (b)	108. (a)
109. (c)	110. (a)	111. (d)	112. (b)	113. (d)	114. (b)	115. (d)
116. (c)	117. (c)	118. (c)	119. (a)	120. (d)	121. (b)	122. (b)
123. (c)	124. (d)	125. (c)	126. (d)	127. (a)	128. (d)	129. (c)
130. (c)	131. (c)	132. (b)	133. (b)	134. (b)	135. (d)	136. (c)
137. (b)	138. (d)	139. (c)	140. (c)	141. (a)	142. (a)	143. (a)
144. (a)	145. (c)	146. (b)	147. (d)	148. (a)	149. (a)	150. (d)
151. (d)	152. (c)	153. (b)	154. (a)	155. (a)	156. (b)	157. (b)
158. (d)	159. (d)	160. (c)	161. (c)	162. (b)	163. (a)	164. (a)
165. (c)	166. (b)	167. (a)	168. (b)	169. (a)	170. (b)	171. (a)
172. ( )	173. ( )	174. ( )	175. (b)	176. (a)	177. (b)	178. (a)
179. (b)	180. (a)	181. ( )	182. (a)	183. (d)	184. (c)	185. (c)
186. ( )	187. (a)	188. (d)	189. ( )	190. (d)	191. (a)	192. (a)
193. (c)	194. (d)	195. (b)	196. (c)	197. (b)	198. ( )	199. ( )
200. (c)	201. (b)	202. (b)	203. (c)	204. (c)	205. (a)	206. (b)
207. (c)	208. (40 to 43)		209. (114 to 117)		210. (3.91 to 4.15)	
211. (b)	212. (d)					

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Assignment - I **Solid State**

1. Sodium transfoms from bcc to hcp crystal structure at about 23 kelvin without change of density in the cubic phase a= 4.23 Å and the hcp phase c/a has ideal value of 1.63. Find the lattice constant.
2. The lattice parameter and the atomic mass of a diamond crystal are 3.57 Å and 12, respectively. Calculate the density of the same.
3. Calculate the lattice constant for a rock salt crystal (density = 2180 kg/m^3), assuming that it has fcc lattice. Mol. wt. of NaCl = 58.5.
4. Calculate the number of atoms per unit cell for an fcc lattice of copper crystal. It is given that a = 3.60Å, at wt. of Cu = 63.6, density of Cu = 8960 kg/m^3 and the Avogadro's number, N = 6.023×10^{26}.
5. Aluminium has an fcc structure. Its density is 2.7×10^3 kg/m^3. Calculate the unit cell dimensions and the atomic diameter.
6. Determine the Miller indices of a plane that makes an intercept of 3Å, 4Å, and 5Å on the coordinate axes of an orthorhombic crystal with a: b: c = 1:2:5.
7. Find the Miller indices of a plane that makes intercepts on a, b and c axes equal to 4Å, 6Å and 4Å in a tetragonal crystal with the cla ratio as 2.
8. Determine the value of "i" in the following Miller-Bravais indices: (10.3), (11.3), (01.4), $(1\bar{1}4)$, (10.4), $(2\bar{2}.4)$, $(2\bar{2}.3)$ (11.0), (32.5) and $(3\bar{4}.2)$
9. Calculate the number of atoms per unit cell for rock - salt crystal. Given a = 5.63Å, mol.wt. of NaCl = 58.5 and the density is 2180 kg/m^3.
10. In a tetragonal crystal, the lattice parameters a = b = 2.42Å, and c = 1.74Å. Deduce the interplanar spacing between consecutive (101) planes.
11. The distance between consecutive (1 1 1) planes in a cubic crystal is 2Å. Determine the lattice parameter.
12. Calculate the atomic density in (100), (110) and (111) planes of copper (fcc) with the lattice parameter of 3.61Å. Can you pack atoms more closely than in (111) plane?
13. Calculate the number of atoms per unit area in (100), (110) and (111) plane of a bcc crystal with the lattice parameter of 2.5Å.
14. $\alpha-Co$ has an hcp structure with lattice spacings of a = 2.51 Å and c = 4.07Å, $\beta-Co$ is fcc, with a cubic lattice spacing of 3.35 Å. What is the difference in density between the two forms?
15. Compute the packing fraction of the 2-D hexagonal lattice structure.
16. The density of copper is 8.96 g/cm^3. It forms an FCC lattice, and has an atomic weight of 63.4 g/mole. Find the length, a, of a side of the cubic unit cell (conventional cell) of copper. Give your result in nanometers.
17. Define lattice constant of a material. Given the silicon lattice constant a = 0.543 nm, calculate the Si-Si bond length. Also calculate the density of silicon, in g cm^{-3}. [Atomic mass of silicon = 28.09, Avogadro's number = 6.022×10^{23} mol^{-1}].
18. Assuming that the phase transition of metallic Fe, from a body centred cubic structure to a face-centred cubic structure does not affect the atomic radius, find the ratio of the density of Fe in the two phases.
19. The distance between (111) planes in a face centered cubic crystal is 2 Å. Determine the lattice parameter and the atomic diameter.

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20. (a) Calcualte the diffraction angle (2θ) for the first three peaks in aluminium powder diffraction pattern. Note that the crystal structure of the Aluminium is fcc and lattice constant is 0.404 nm.
(b) If the lattice constant of Al was larger than 0.404 nm. Describe how pattern would change?

21. In a powder X-ray diffractoin pattern using X-rays of wave length 1.54Å, three consecutive first order peaks are observed at '2θ' values of 60°, 90° and 112°. If system is cubic and peaks at 90°. Corresponds to (220) planes.
(a) Calculate the value of lattice constant (a)
(b) Obtain the miller indices and identify the system.

22. A body-centred cubic (bcc) cell has a lattice constant a
(a) How many atoms are there in a cubic unit cell?
(b) What is the spacing between the (1 1 1) planes?
(c) What will be the Bragg's diffraction angle for scattering from the (100) planes of the crystal?

23. A transmission electron microscope is use to produce a diffraction ring for the polycrystalline sample of copper the ring (1 1 1) is 12 nm from centre. How far would (200) ring be from the centre.

24. Calculate the packing fraction for
(a) (110) and (111) planes of sc.
(b) (100), (110) and (111) of fcc.
(c) (100), (110) and (111) of fcc
(d) Triangular lattice in hcp crystal having each side (a). Where a is lattice parameter.

25. Assume the potential energy of two particles in the field of each other is given by

$$U(R) = \frac{-A}{R} + \frac{B}{R^9}$$

Where A and B are constants.
(a) Calculate equilibrium distance.
(b) Show that stable configuration, the energy of attracton is nine times the energy of repulsion.
(c) Show that potential energy of the system under stable configuration is $\frac{8A}{9R}$

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Assignment - 2 Solid State

1. As we know for diffraction studies of crystal, the wavelength of incident wave should be around 1Å. X-rays, neutrons and electrons used to explore the crystal structure, then compare the energies of X-rays, neutrons and electrons for 1Å wavelength also find out which one better for the studies of
   (i) Crystal lattice structure (ii) Surface structure (iii) Magnetic structure

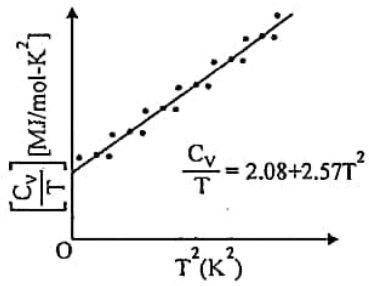
2. (a) Show that as diffraction angle increases accuracy in calculation of lattice parameter increases
   (b) In an X-ray diffraction experiment using $\lambda_{cu} = 1.542\text{Å}$, the (311) planeof a cubic lattice gives a dffraction peak at $\theta = 45^\circ$ with an uncertaininty of $\pm 0.2^\circ$. Calculate the value of lattice parameter and estimated error.

3. Consider the monoatomic lattice in which second nearest neighbour interaction is also considered. The dispersion relation for phonon is given by

$$\omega^2 = \left(\frac{4C}{m}\right)\sin^2\left(\frac{Ka}{2}\right)\left[1+4\cos^2\left(\frac{Ka}{2}\right)\right]$$

   Calculate the velocity of sound in the solid.

4. The experimental heat capacity of potassium (K) is plotted in the graph below:



   from this graph calculate
   (a) Fermi temperature (T_F) (b) Fermi energy (E_F)
   (c) Debye temperature (θ_D) (d) Debye frequency (ν_D)
   (e) If potassium is monovalent bcc, calculate its lattice parameter (a)
   (f) Speed of sound in potassium (K)

5. (a) Consider two branches of a phonon spectrum of a one dimensional lattice $\omega_1(\bar{k}) = A|\sin(k)|$ and $\omega_2(\bar{k}) = B(2+\cos(k))$
   (a) in the Debye phonon dispersion approximations give the phonon dispersion reation.
   (b) Band width of optical branch, Band width of acoustical branch and Band gap

* Dispersion relation * Band theory
Imp-

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6. What is the temperature at which there is a 1% probability that an energy state lying 0.2 eV below the fermi level in gold is empty. E_F of gold is 5.4 eV.

7. Calculate the thermal conductivity of sodium (Na) at 300K. The e^- concentration and mean free time (τ) for sodium is 2.65×10^{28} / m^3 and 3×10^{-14} sec respectively.

8. Take the Fermi energy of silver to be 5.52 eV.

   (a) Find the corresponding velocity of conduction electron.

   (b) If the resistivity of silver at room temperature is $1.62 \times 10^{-8}\ \Omega$m estimate the average time between collisions.

   (c) Determine the mean free path. Assume the number of conduction electrons as $5.86 \times 10^{28}\ m^{-3}$.

9. Aluminium is trivalent with atomic weight 27 and density 2.7 g/cm^3, while the mean collision time between electrons is 4×10^{-14}s. Calculate the current flowing through an aluminium wire 20m long and 2mm^2 cross-sectional area when a potential of 3V is applied to its ends.

10. Given that the inter-collision time in copper is 2.3×10^{-14} S, calculate its thermal conductivity at 300K. Assume the Wiedemann-Franz constant is $C_{WF} = 2.31 \times 10^{-8} W \Omega K^{-2}$.

11. The Fermi energy in gold is 5.54 eV (a) calculate the average energy of the free electrons in gold at 0°K. (b) Find the corresponding speed of free electrons (c) What temperature is necessary for the average kinetic energy of gas molecules to posses this value?

12. The density of copper is 8.94g/cm^3 and its atomic weight is 63.5 per mole, the effective mass of electron being 1.01. Calculate the Fermi energy in copper assuming that each atom gives one electron.

13. Find the probability of occupancy of a state of energy (a) 0.05eV above the Fermi energy (b) 0.05eV below the Fermi energy (c) equal to the Fermi energy. Assume a temperature of 300K.

14. What is the probability at 400K that a state at the bottom of the conduction band is occupied in silicon. Given that $E_g = 1.1$eV.

15. The Debye temperature θ for iron is known to be 360K. Calculate ν_m, the maximum frequency.

16. (a) A fcc crystal of cube side a. Calculate the fermi energy for (111) plane and compare this fermi energy to the fermi energy of (100) plane. Here we are assuming that fcc crystal giving two conduction electrons per atom.
    (b) Calculate the Fermi energy and wave vector for simple cubic crystal in one dimension, cube side is a.

17. Sodium metal with bcc structure has radius of sodium atom to be 1.85 Å. Calculate
    (a) Fermi energy, fermi velocity and diameter of fermi sphere.
    (b) Electrical resistavity from drude model. (Given: $\tau = 3 \times 10^{-14}$ second)

18. Sodium has bcc structure with atomic radius 1.82 Å and one valence electron per atom. Resistivity of Na at 20°C is $\rho = 1.72 \times 10^{-8}\ \Omega - m$. Calculate:

    (i) Characteristic time (τ) from Drude model.

    (ii) Fermi energy

    (iii) Diameter of Fermi sphere $= 2K_F$

    (iv) Mean free path (λ). $\lambda = v_F \tau$

    (v) Fermi temperature (T_F). $E_F = kT_F$

19. Lattice vectors of rectangular primitive lattice is given as $\bar{a} = 2\hat{i}$, $\bar{b} = \hat{j}$ (a and b are in Å).

    (i) Calculate the area of all the Brillouin zones.
    (ii) Radius of fermi circle.
    (iii) Fermi energy.
    (iv) Average velocity of electrons at which they are moving in crystal.

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20. Calculate the fermi energy of electron gas in copper. The density of copper at 300 K is 8.96 g/cm and atomic weight = 63.5. Take one conduction electron per atom.

21. Calculate drift velocity and mobility of electron in a copper wire of length 2.4 m when a potential differene of 32v is maintained across its ends. Assume that each copper atom contributes one conduction electron. Avogadro number $N = 6.02\times10^{26}$ / kg mole.

Resistivity $\rho = 0.172\times10^{-7}$ ohm − m

Density $= 8.9\times10^{3}$ kg / m^3

Atomic weight = 63.5.

22. A body centred cubic metal having electrons as charge carries density of electrons 2.64×10^{28} /m^3. Using free electron theory calculate:
(i) Fermi energy of metal in eV.
(ii) Lattice constant of solid in Ang.
(iii) Fermi momentum.

23. Copper has monovalent fcc structure. Calculate the diameter of fermi sphere and shortest distance in first Brillouin zone.

24. $E(\bar{k}) = E_0 - 24\left[\cos(k_x a)+\cos(k_y a)\right]$

where $k^2 = k_x^2 + k_y^2$

Calculate:
(i) Band width of lowest band.
(ii) Plot first Brillouin zone.
(iii) E–k diagram along [10] and [11] direction.

25. A hypothetical semi conductor has a conduction band that can be described by $E_{cb} = E_1 - E_2\cos(ka)$

and a valence band that can be described by $E_{vb} = E_3 - E_4\sin^2\left(\frac{ka}{2}\right)$

where $E_3 < (E_1 - E_2)$ and $\frac{-\pi}{a} \le k \le \frac{\pi}{a}$

(i) Sketch the variation of the energy of two bands as function of k for $-\frac{\pi}{a} \le k \le \frac{\pi}{a}$
(ii) Band width of the conduction band and that of the valence band?
(iii) Band gap of the material?
(iv) What is the effective mass of the electron at the bottom of the conduction band?

26. For a solid energy is given by $E(k) = E_0 - c\cos\left(\frac{k_x a}{2}\right)\cos\left(\frac{k_y a}{2}\right)$

(a) Expand $E(\bar{k})$. (b) Band width of the band (c) Effective mass at $(0,\pi/a)$ and at $(0,0)$.

27. The energy band relation in a linear chain with interatomic distance a is given by $E_k = E_0 - T\cos(ka)$. When width of this band is increased by 20%. Calculate the percentage change in the effective mass of electron at the bottom of the band.

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Assignment - 3 Solid State

1. The band structure of a simple cubic lattice is given by $E = E_0 - A(\cos ka + \cos ka + \cos ka)$ where a is the lattice constant and A is a positive constant.
   (a) Find the effective mass of the electron at values of k corresponding to the top and bottom the band.
   (b) For a particular simple cubic solid with a lattice constant a = 2.5Å, the effective mass of the electron at the bottom of the band is equal to the free electron mass. Find the value of the constant A and the width of the band in eV.
2. A certain metal has a body centered cubic space lattice with cube side a. The electrons are assume to bc free.
   (a) If the metal is monovalent, what is the radius of fermi sphere?
   (b) For the electrons density of part (a) the fermi sphere does not reach the Brillouin zone boundary. What is the minimum value of the free electron density so that the fermi sphere just touches the zone boundary?
3. An organic conductor has recently been found by optical studies to have $\omega_p = 1.80\times10^{15}$ sec^{-1} for plasma frequency and $\tau = 2.83\times10^{-15}$ sec for the electron relaxation time at room temperature.
   (a) Calculate electrical conductivity
   (b) From crystal and chemical structure; the conduction electron concentration is 4.7×10^{21} /cm^3. Calculate effective mass m*.
4. Calculate the hall coefficient of sodium (Na) on based on free electron theory. Sodium has bcc structure and side of cube is a = 4.28Å.
5. A sample of silicon of thickness 200μm is doped with 10^{23} phosphorus atoms/m^3. If the sample is kept in a magnetic field of 0.2 wb/m^2 and a current of 1 mA is passed through the sample, calculate the hall voltage produced.
6. Hall coefficient of a body-centred cubic metal having electrons as charge carriers is $R_H = -2.36\times10^{10}$ m^3/C. Using free electron theory. Calculate the lattice constant of metal.
7. A silicon bar of length l = 10.0 mm and cross-section $a^2 = 0.5\times0.5$ mm^2 carries current I = 5mA along its length in x-direction. It is placed between pole pieces of an electron magnet of field B_z = 1.6 tesla along z-direction. A pairs of voltage probles, plaed across the cross-section of the sample and perpendicular to the current and field, measures a voltage, $V_H = -5$mV.
8. The donor concentration of an n-type semiconductor (E_g = 2.303 eV) is $N_D = 2\times10^{16}$ /cm^3. Find the temperature (in terms of Boltzman constant) at which the semiconductor starts behaving like an intrinsive semiconductor. The density of states in the conduction and the valence bands are 4×10^{19} /cm^3 and 1×10^{19}/ cm^3 respectively.
9. (a) Show that minimum conductivity of a semi conductor sample occurs. When $n_0 = n_i\sqrt{\frac{\mu_p}{\mu_n}}$
   (b) What is the expression for the minimum conductivity σ_{min} ?
   (c) Calculate σ_{min} for Si at 300K and compare with the intrinsic conductivity.

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10. A Si solar cell has a short circulated current of 100 mA and an open circuit voltage of 0.8 volt under full solar illumination. The fill factor is 0.7. What is the maximum power delivered to a load by this cell?

11. A Si solar cell with a dark current Ith of 5 nA is illuminated such that the short circuit current is 200 mA. Plot I-V characteristics for the cell? [Temperature is T = 300K].

12. A Si solar cell 2cm × 2cm with Ith = 32nA has an optical generation rate of 10^8 EHA cm^3–sec within $L_p = L_n = 2\mu m$ of the junction. If the depletion width is 1 μm, calculate the short-circuit current and open circuit voltage for this cell?

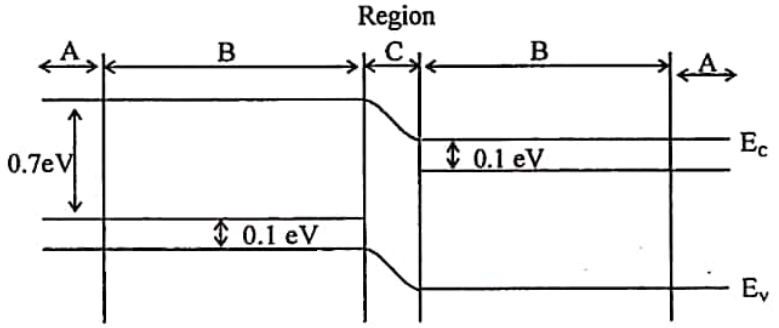
13. If one LED made from a semiconductor with a band gap of 2.5 eV. What wavelength of light will it emit? Can you use it to efficiently detect photons of wavelength 1900 nm and 100 nm?

14. A solar cell has a short circuit current of 50 mA and an open circuit voltage of 0.7V under full illumination. What is the maximum power delivered by this cell if the fill factor is 0.8?

15. A photo conductive cell, 1×1×1 mm^3/Cds crystal is illuminated with light of wavelength 450 nm and intensity 1 mW/cm^2. Assuming quantum efficiency of unity. Calculate the number of electron hole pairs (EHP/second) generated per second. Given the energy band gap of Cds, $E_g = 2.6$ eeV.

16. What wavelength of light can be observed by a silicon photodetector band gap silicon = 1.1 eV.

17. Consider a band diagram of a simple light-emitting diode. Assume essentially all recombination is direct and result in light emission. The forward biased current consists of holes injected from a conctact on the left and electrons injected from a contact on the right.



(a) In which region would you expect the optical recombination rate to be greatest?

(b) What is the approximation energy of emitted photons is eV?

(c) For steady state current I = 10 mA, assuming all photons escape, what is the optical output power consists with your answer to part (b)

(d) If the voltage drop across depletion region is 0.4 volt, what is the separation of quasi fermi level in region C. How can this be less than the total forward bias of 1.4 volt?

18. A 0.46μm thick sample of GaAs is illuminated with monochromatic light of hν = 2eV. The absorption coefficient α is 5×10^4 cm^{-1}. The power incident on the sample is 10 mW. (Band gap $E_g = 1.43$ eV)

(a) Find the total energy absorbed by the sample per second (J/sec).

(b) Find the rate of excess thermal energy given up by the electrons to the lattice before recombination.

(c) Find the number of photons per second given off from recombination events assuming perfect quantum efficiency.

19. A Si pin photodiode has an active light receiving area of dimensions (0.4mm × 0.4 mm). When radiation of wavelength 700 nm and intensity 0.1 mW/cm^2 is incident, it generated a photon current of 20 nA. Calculate the

(a) Responsivity in units of A/W, and the

(b) Qunatum efficiency of hte photodiode at 700 nm (within an accuracy of 1%).

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20. (a) Calculate the static dielectric constant (ε_r) of solid argon using classius-Mossotti equation and the following data?

$\alpha_e = 1.7\times10^{-40}\ F.m^2$, atomic mass of Avogadro number

Ar = 39.95 g/mole,

N = 6.02×10^{23} per mole, density of solid Ar

= 1.8 gm/cm^3.

(b) Will result be affected if (ε_r) is calculated from $P=\varepsilon_0(\varepsilon_r-1)E=N\alpha_e E$. Give reason for your answer.

21. Calculate the dielectric constant for saturated water vapour at 20°C given the density of saparated water vapour is 17.3 g/m^3.

22. A radiation of 1 kW/m^2 incident on the solar panel of area 1×1.6 m^2. The light has wavelength $\lambda = 732\ nm$.
(i) Determine the number of photons/second incident on the panel.
(ii) Calculate the current generated in (A) if panel has 100% efficiency.

23. Iron has bcc structure with lattice constant a = 2.86Å. The saturation magnetisation of iron is 1.74×10^6 amp/m. Calcualte magnetic moment (μ) of Fe atom.

24. Calculate saturation magnetisation for Nickel and cobalt having densities equal to 8.67 and 9.04 gm/cm^3, respectively. Number of Bohr magnetons per atom are 1.72 for Co and 0.54 for Ni. Atomic masses are M_{CO} = 58.93 and M_{Ni} = 58.69.

25. The diamagnetic susceptibility due to the ion cores in metallic copper is -0.20×10^{-6} knowing the densities of Cu is 8.93 g/cm^3 and that its atomic weight is 63.5. Calculate the average radius of Cu ion.

26. The binding energy of a copper pair at absolute zero according to BCS theory is a about 3.5 KT_c. Where 'K' is Boltzmann constant and T_c is critical temperature. The critical temperature of type I super conductor is 10K.
(a) What is the energy gap in electron volt.
(b) Calculate the wavelength of photons whose energy is the just sufficient to break the copper pair in this super conductivity
(c) In which region of electromagnetic spectrum do this photon lie?

27. In lead (Pb) the binding energy of Cooper pair is 10 meV. Calculate
(i) Critical temperature of Pb.
(ii) Maximum wavelength of photons require to break the cooper pair.

28. For BCS super conductor T_C = 5K, E_F = 5 eV, and *n* density of conduction electrons = 10^{29}/m^3. Evaluate
(a) Approximate magnitude of energy gap in (eV)
(b) Density of super electrons close to T = 0K.

29. The maximum wavelength of photons require to break the cooper pair in Sn(tin) is 1.08×10^{-3}m. Calculate the critical temperature of Sn.

30. Calculate the frequency of AC current flows across Josephson junction. If 1.5μV potential applied on the junction. Also calculate switching time of the junction.

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Assignment - Experimental Methods

1. In which counter, for detection of thermal neutron baron is introduced in the form of BF_3 ?
(a) Ionisation Chamber (b) Proportional counter
(c) G.M. counter (d) All of the above

2. The pulse rise time is defined as the time taken by the pulse :
(a) To go from 10% to 90% of its amplitude
(b)To go from 0% to 100% of its amplitude
(c) To go from 0% to 90% of its amplitude
(d) To go from 10% to 100% of its amplitude

3. In ionisation types of vaccume gauges, the pressure of P is :
(a) $P \alpha I_G / I_P$ (b) $P \alpha I_P / I_G$
(c) $P \alpha I_K / I_G$ (d) $P \alpha I_P / I_K$
Where I_G = Grid current, I_K = Cathode current
I_P = Plate current

4. Radiation Pyrometers are usded in the temperature range of :
(a) 0 – 500°C (b) 500 – 1000°C (c) –250 – 500°C (d) 1200 – 2500°C

5. The mean deviation $\bar{D}$ in terms of deviation from the mean value of n readings is :
(a) $\frac{\Sigma|d|}{n}$ (b) $\frac{\Sigma d}{n}$ (c) $\frac{\sqrt{\Sigma d^2}}{n}$ (d) $\sqrt{\frac{\Sigma d^2}{n}}$

6. The Gaussian distribution can be mathematically expressed as :
(a) $y=\frac{h}{\sqrt{\pi}}\exp\left(h^2x^2\right)$ (b) $y=\frac{h}{\pi}\exp\left(-h^2x^2\right)$ (c) $y=-\frac{h}{\sqrt{\pi}}\exp\left(h^2x^2\right)$ (d) $y=\frac{h}{\sqrt{\pi}}\exp\left(-h^2x^2\right)$

7. One of the organic crystal used in scintillator is :
(a) Anthracene (b) Urea
(c) Xylene (d) Benzene

8. In a Hall effect experiment donor density $=10^{21}m^{-3}$, $B=0.5\ W/m^2$, $J=500\ amps/m^2$, thickness of the sample = 3 mm. calculate the Hall voltage :
(a) 4.7 mV (b) 7.4 mV (c) 8.7 mV (d) 3.9 MV

9. The quenching agents used in GM counter is :
(a) Ethyl alcohol or Halogens (b) Ar
(c) He (d) CH_4

10. In order to obtain good gain stability in a negative voltage feedback amplifier (A_o = voltage gain without feedback; β= feedback fraction) the required condition is :
(a) $A\beta=1$ (b) $A\beta>>1$ (c) $A\beta<1$ (d) None of the above

11. Which of the following statement is false :
(a) CR differentiator is a high pass filter
(b) RC integrator is a low pass filter
(c) (RC) – $(CR)^n$ shaping produce Gaussian shape
(d) Pole zero cancellation removes the undershoat

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12. At the input on amplifier has a signal voltage level of 3μV and a noise voltage level of 1 μV, the signal to noise ratio at the input is :
(a) 1 (b) 3 (c) 9 (d) 27

13. Which of the following statement is wrong?
(a) In photoemission, absorption of photon frees an electron from material
(b) In photo voltaic effect, absorption of photon leads to the generation to a potential defference across a junction between two material
(c) In photoconductivity , absorption of photon increases the number of charge carrier in a material
(d) In thermopile, absorption of photons causes change in resistance

14. A 0 – 300V voltmeter has an error of ± 2% of full scale deflection. What would be the range of reading if true voltage is 30V.
(a) 24V – 36 V (b) 29.4V – 30.6 V (c) 20 V – 40 V (d) None of these

15. Johnson noise is :
(a) caused by thermal agitation of free electrons carrying current there by modulating the current
(b) Noise carried into a circuit through conductors
(c) Noise of an electromagnetic origin that is radiated into a circuit
(d) Shat noise which results from random emission of electrons across a p-n junction.

16. In solid state detectors, contact is made with the n-type silicon layer by a thin evaporated film of :
(a) Gold (b) Aluminium (c) Silver (d) Alloy

17. The impedance matching between detector and Pri-amplifier is required as it :
(a) Reduce the noise level is signal (b) Increases the band width of the Pre-amplifier
(c) Reduce the reflection of signal (d) All of the above

18. The variance of a mean in which of the following is wrongly matched

(a) $\frac{\sigma_u}{u} = \pm m\sigma_x$ for $u = x^{\pm m}$ (b) $\frac{\sigma_u}{u} = \pm(b\,\ell n\, a)\,\sigma_x$ for $u = a^{\pm bx}$

(c) $\frac{\sigma_u}{u} = \sqrt{\frac{\sigma_x^2}{x^2} + \frac{\sigma_y^2}{y^2}}$ for $u = \pm axy$ (d) $\sigma(\bar{x}) = \sqrt{N}$ for $\bar{x} = \frac{1}{N}\Sigma x$

19. The flow process for which the mean free path of the molecules is large compared with the dimensions of the apparatus is :
(a) Viscous flow (b) Molecular flow (c) Knudson flow (d) None of these

20. The sensitive region of a p-n junction particle detector is the :
(a) P-region (b) Depletion region
(c) n-region (d) P, n and Depletion region

21. The length and radius of a perfect cylinder are each measured with an RMS error of 1%. The RMs error on the inferred volume of the cylinder is roughly
(a) 1.7% (b) 3.3% (c) 0.5% (d) 1%

22. A resistance strain gauge is fastened to a steel fixture and subjected to a stress of 1000 kg/m^2. IF the gauge factor is 3 and the modulus of elasticity of steel is 2×10^{10} kg / m^2, then the fractional change in resistance of the strain gauge due to the applied stress is
(Note: The gauge factor is defined as the ratio of the fractional change in resistance to the fractional change in lenght.)
(a) 1.5×10^{-7} (b) 3.0×10^{-7} (c) 0.16×10^{-10} (d) 0.5×10^{-7}

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23. Consider a sinusoidal waveform of amplitude 1V and frequency f_0. Starting from an arbitrary intial time, the waveform is sampled at intervals of $1/(2f_0)$. IF the corresponding Fourier spectrum peaks at a frequency $\bar{f}$ and an amplitude $\bar{A}$, then

(a) $\bar{f} = 2f_0$ and $\bar{A} = 1V$ (b) $\bar{f} = f_0$ and $0 \le \bar{A} \le 1V$

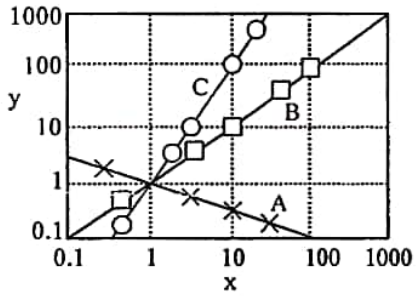
(c) $\bar{f} = 0$ and $\bar{A} = 1V$ (d) $\bar{f} = \frac{f_0}{2}$ and $\bar{A} = \frac{1}{\sqrt{2}} V$

24. The acceleration due to gravity g is determined by measuring the time period T and the length L of a simple pendulum. If the uncertainties in the measurements of T and L are ΔT and ΔL respectively, the fractional error $\Delta g/g$ in measuring g is best approximated by

(1) $\frac{|\Delta L|}{L} + \frac{|\Delta T|}{T}$ (2) $\frac{|\Delta L|}{L} + \frac{|2\Delta T|}{T}$

(3) $\sqrt{\frac{|\Delta L|^2}{L} + \frac{|\Delta T|^2}{T}}$ (4) $\sqrt{\left(\frac{\Delta L}{L}\right)^2 + \left(\frac{2\Delta T}{T}\right)^2}$

25.. Three sets of data *A*, *B* and *C* from an experiment, represented by ×, □ and ○, are plotted on a log-log scale. Each of these are fitted with straight lines as shown in the figure.



The functional dependence $y(x)$ for the sets A, B and C are, respectively

(a) $\sqrt{x}, x$ and x^2 (b) $-\frac{x}{2}, x$ and $2x$

(c) $\frac{1}{x^2}, x$ and x^2 (d) $\frac{1}{\sqrt{x}}, x$ and x^2

26. One gram of salt is dissolved in water that is filled to a height of 5 cm in a beaker of diameter 10 cm. The accuracy of length measurement is 0.01. The accuracy of length measurement is 0.01 cm while that of mass measurement is 0.01 mg. When measuring the concentration C, the fractional error $\Delta C/C$ is

(a) 0.8% (b) 0.14% (c) 0.5% (c) 0.28%

27. A resistance is measured by passing current through it and measuring the resulting voltage drop. If the voltmeter and the ammeter have uncertainties of 3% and 4%, respectively, then

A. The uncertaintty in the value of resistance is:

(a) 7.0 % (b) 3.5 % (c) 5.0 % (d) 12.0 %

B. The uncertainty in the computed value of the power dissipated in resistance is

(a) 7% (b) 5% (c) 11% (d) 9%

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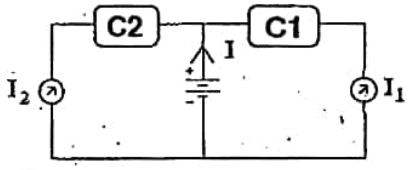
28. A battery powers two circuits C_1 and C_2 as shown in t the figure



The total current I drawn from the battery is estimated by measuring the currents I_1 and I_2 through the individual circuits. If I_1 and I_2 are both 200 mA and if the errors in their measurement are 3 mA and 4mA respectively, the error in the estimate of I is:

(a) 7.0 mA (b) 7.5 mA (c) 5.0 mA (d) 10.5 mA

Answer Key: Experimental Methods

1. (b)	2. (a)	3. (b)	4. (d)	5. (a)	6. (d)	7. (a)
8. (a)	9. (a)	10. (c)	11. (c)	12. (c)	13. (d)	14. (a)
15. (a)	16. (a)	17. (c)	18. (d)	19. (b)	20. (b)	21. ( )
22. ( )	23. ( )	24. (d)	25. (d)	26. (d)	27._A(c_	27_B(b)
28. (c)						

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